Sciences of Europe

No 187 (2026)

Sciences of Europe
(Praha, Czech Republic)

ISSN 3162-2364
The journal is registered and published in Czech Republic.
Articles in all spheres of sciences are published in the journal.

Journal is published in Czech, English, Polish, Russian, Chinese, German and French, Ukrainian.
Articles are accepted each month.
Frequency: 24 issues per year.
Format - A4
All articles are reviewed
Free access to the electronic version of journal

Edition of journal does not carry responsibility for the materials published in a journal.
Sending the article to the editorial the author confirms it's uniqueness and takes full responsibility for possible consequences for breaking copyright laws.

Chief editor: Petr Bohacek
Managing editor: Michal Hudecek

- Jiří Pospíšil (Organic and Medicinal Chemistry) Zentiva
- Jaroslav Fähnrich (Organic Chemistry) Institute of Organic Chemistry and Biochemistry Academy of Sciences of the Czech Republic
- Rasa Boháček – Ph.D. člen Česká zemědělská univerzita v Praze
- Naumov Jaroslav S., MD, Ph.D., assistant professor of history of medicine and the social sciences and humanities. (Kiev, Ukraine)
- Viktor Pour – Ph.D. člen Univerzita Pardubice
- Petrenko Svyatoslav, PhD in geography, lecturer in social and economic geography. (Kharkov, Ukraine)
- Karel Schwaninger – Ph.D. člen Vysoká škola báňská – Technická univerzita Ostrava
- Václav Pittner -Ph.D. člen Technická univerzita v Liberci
- Dudnik Oleg Arturovich, Doctor of Physical and Mathematical Sciences, Professor, Department of Physical and Mathematical management methods. (Chernivtsi, Ukraine)
- Konovalov Artem Nikolaevich, Doctor of Psychology, Professor, Chair of General Psychology and Pedagogy. (Minsk, Belarus)

«Sciences of Europe» -
Editorial office: Křižíkova 384/101 Karlín, 186 00 Praha

E-mail: info@european-science.org
Web: www.european-science.org

CONTENT

AGRICULTURAL SCIENCES

Siruk Yu., Moroz V., Turko M.
DYNAMICS OF TAXATION INDICATORS AND THE PHYTOSANITARY CONDITION OF *PINUS SYLVESTRIS* L. FOREST CULTURES ON LANDS RECLAIMED AFTER ILMENITE MINING IN THE SHERSHNIV FORESTRY.....4

ART STUDIES

Seyidov T.
TRANSFORMATION OF PSYCHOLOGICAL GOALS INTO PHYSICAL ACTIONS IN THEATRICAL ART 9

Zhusip D., Medetkyzy N., Sultanova A.
THE DEVELOPMENT OF A MUSICAL THEATER ACTOR'S VOICE.....13

BIOLOGICAL SCIENCES

Sharifova G., Mammadova F.
THE ROLE OF LIPID METABOLISM INDICATORS, ENDOTHELIAL DYSFUNCTION PARAMETERS, AND INFLAMMATORY MARKERS IN THE PATHOGENESIS OF HYPERTENSIVE RETINOPATHY.....21

CHEMICAL SCIENCES

Koshchii I., Klimko Yu.
SYNTHESIS AND ANTIMICROBIAL ACTIVITY OF SOME ADAMANTYL-CONTAINING HYDRAZONES 24

EARTH SCIENCES

Isgandarov E., Jafarli L.
POSSIBILITIES OF ANALYTICAL CONTINUATION OF GRAVITY AND ITS GRADIENTS FOR PREDICTION OF CROSS-SECTION.....30

ECONOMIC SCIENCES

Sherifov O.
ANALYSES OF TAX STRUCTURE AND ECONOMIC GROWTH 36

Uktamova N.
THE CURRENT STATE OF FINANCING EDUCATION THROUGH PUBLIC-PRIVATE PARTNERSHIP AND ISSUES OF ITS IMPROVEMENT 46

HISTORICAL SCIENCES

Aliyev I., Aliyeva K.
POLITICAL AND MILITARY ACTIVITIES OF THE KHWARAZMSHAHS IN AZERBAIJAN 50

MEDICAL SCIENCES

Logai V.
EXPERIMENTAL STUDY OF ULTRASTRUCTURAL CHANGES IN THE ORAL MUCOSA OF RATS AFTER FIREARM AND NON-FIREARM INJURIES TO THE MAXILLOFACIAL REGION.....55

Wang Chenyu, Zhang Ge
"HARMONIZING FORM AND SPIRIT": A STUDY ON THE REHABILITATION MECHANISM OF CHRONIC STRAIN IN VIOLIN PLAYING FROM THE PERSPECTIVE OF TRADITIONAL CHINESE MEDICINE.....59

PEDAGOGICAL SCIENCES

Ismayilova A.
THE LEVEL OF DEVELOPMENT OF EDUCATIONAL COMPETENCIES: IMPLEMENTATION IN CURRICULUM MATERIALS 64

Gantsetseg Sanjmyatav, Oyun-Erdene Erdenebileg
A COMPARATIVE EVALUATION OF ESP COURSE IMPLEMENTATION USING THE CIPP MODEL 68

Abiltayeva M., Kalimoldayeva A.
ADAPTATION OF INTERNATIONAL QUALITY MANAGEMENT PRACTICES IN HIGHER EDUCATION INSTITUTIONS OF KAZAKHSTAN 75

PHARMACEUTICAL SCIENCES

Bershadskyi S., Klopotiuk V., Garlitska N.
MEASURING THE SURFACE TENSION OF NASAL MEDICINAL PRODUCTS 79

SOCIAL SCIENCES

Valizada K.
THE MEANING OF LIFE IN EASTERN AND WESTERN PHILOSOPHY: A COMPARATIVE ANALYSIS 82

Ying Chen
TRENDS IN THE STUDY OF SMART HEALTHCARE SYSTEMS FOR THE ELDERLY IN CHINA: A BIBLIOMETRIC ANALYSIS 92

TECHNICAL SCIENCES

Ahmadova A., Asadova S.
THE ROLE OF BLOCKCHAIN TECHNOLOGY IN CYBERSECURITY: APPLICATIONS, CHALLENGES AND PERSPECTIVES 108

Baratzada R., Salimov V.
DEVELOPMENT OF A CLASSIFICATION MODEL FOR A MANUFACTURING ENTERPRISE BASED ON THE DECISION TREE METHOD 111

Davrishova I., Hesenzade G.
INVESTIGATION OF OPTICAL TRANSMITTER AND RECEIVER SYSTEMS IN ARTIFICIAL INTELLIGENCE ... 116

Bolotov T., Abdusamatov K.B., Ulan uulu B.
INVESTIGATION AND OPTIMIZATION OF THE COMPOSITION AND PROPERTIES OF DECORATIVE CEMENT COMPOSITIONS WITH THE ADDITION OF TRAVERTINE (SEASHELL) 121

Sultan Y., Kiyalbay S.
THEORETICAL PREREQUISITES FOR THE COMBINATION OF PROCESSES IN THE CREATION OF A ROADSIDE SERVICE FACILITY 125

AGRICULTURAL SCIENCES

ДИНАМІКА ТАКСАЦІЙНИХ ПОКАЗНИКІВ ТА ФІТОСАНІТАРНИЙ СТАН ЛІСОВИХ КУЛЬТУР *PINUS SYLVESTRIS* L. НА РЕКУЛЬТИВОВАНИХ ПІСЛЯ ВИДОБУТКУ ІЛЬМЕНІТУ ЗЕМЛЯХ ШЕРШНІВСЬКОГО ЛІСНИЦТВА

Сірук Ю.В.
кандидат с.-г. наук, доцент,
Поліський національний університет, м. Житомир
Мороз В.В.
кандидат с.-г. наук, доцент,
Західноукраїнський національний університет, м. Тернопіль
Турко М.В.
магістр кафедри лісового та садово-паркового господарства,
Поліський національний університет, м. Житомир

DYNAMICS OF TAXATION INDICATORS AND THE PHYTOSANITARY CONDITION OF *PINUS SYLVESTRIS* L. FOREST CULTURES ON LANDS RECLAIMED AFTER ILMENITE MINING IN THE SHERSHNIV FORESTRY

Siruk Yu.
Candidate of Agricultural Sciences, Associate Professor
Polissia National University, Zhytomyr
Moroz V.
Candidate of Agricultural Sciences, Associate Professor
West Ukrainian National University, Ternopil
Turko M.
Master's Student, Department of Forestry and Horticulture
Polissia National University, Zhytomyr
DOI: 10.5281/zenodo.19825740

АНОТАЦІЯ

Досліджено динаміку таксаційних показників і фітосанітарний стан лісових культур сосни звичайної (*Pinus sylvestris* L.), створених на рекультивованих землях Шершнівського лісництва Коростенського надлісництва (Філія «Столичний лісовий офіс» ДП «Ліси України»). Загальна площа таких насаджень становить понад 583 га (9,9% від площі лісництва). На основі аналізу 62 таксаційних виділів площею 417,8 га та матеріалів чотирьох лісовпорядкувань (1977, 1987, 1997, 2017 рр.) встановлено стале підвищення бонітету від III до I класу, трансформацію типів лісу з борових (А) у суборові (В) умови та зростання стовбурного запасу. Виявлено, що 67,0% соснових насаджень зосереджені в осередках кореневої губки (*Heterobasidion annosum* (Fr.) Bref.). На трьох тимчасових пробних площах у 52-річних деревостанах підтверджено статистично достовірний зв'язок між часткою листяних порід (акація біла, береза повисла) у складі деревостану та індексом санітарного стану: ділянка зі складом 9Сз1Акб+Бп характеризувалася найнижчим індексом – 2,6 проти 3,1–3,3 для чистих сосняків. Продуктивність змішаних насаджень є вищою на 3,3–15,0%. Обґрунтовано рекомендацію переходу від монокультур до змішаних схем садіння.

ABSTRACT

The study investigates the dynamics of forest mensurational indicators and the phytosanitary condition of Scots pine (*Pinus sylvestris* L.) plantations established on reclaimed lands of Shershnivske Forestry of Korosten Forest District (Branch "Capital Forest Office", State Specialized Enterprise "Forests of Ukraine"). The total area of such plantations exceeds 583 ha (9.9% of the forestry area). Analysis of 62 forest inventory plots covering 417.8 ha and four inventory cycles (1977, 1987, 1997, 2017) showed a consistent improvement of site quality class from III to I, transformation of forest site types from dry pine forests (A) to more productive pine-oak suborys (B), and an increase in growing stock. It was established that 67.0% of pine stands are located in foci of root rot (*Heterobasidion annosum* (Fr.) Bref.). In three temporary sample plots in 52-year-old stands, a statistically significant relationship was confirmed between the proportion of deciduous species (white acacia, silver birch) and the sanitary condition index: the plot with composition 9Ps1WA+SB showed the lowest index of 2.6 compared to 3.1–3.3 for pure pine stands. Mixed stands showed 3.3–15.0% higher productivity. A recommendation to transition from monocultures to mixed planting schemes is substantiated.

Ключові слова: лісова рекультивація, сосна звичайна, Шершнівське лісництво, таксаційні показники, коренева губка, змішані насадження, індекс санітарного стану, біологічна стійкість.

Keywords: forest reclamation, Scots pine, Shershnivske Forestry, mensurational indicators, root rot, mixed stands, sanitary condition index, biological resistance.

Вступ. Діяльність Іршанського гірничо-збагачувального комбінату з видобутку корисних копалин у Житомирському Поліссі призвела до формування значних площ техногенних ландшафтів із глибоко трансформованим едафічним середовищем. Лісова рекультивація порушених ділянок, розпочата ще у 1970-х рр., сьогодні представлена різновіковими насадженнями сосни звичайної, які перебувають у середньовіковому та пристигаючому стані [4, 12]. Незважаючи на успішне первинне заліснення та задовільну продуктивність у молодняковому віці, більшість монокультурних соснових деревостанів нині зазнають прогресуючого ураження кореневою губкою (*Heterobasidion annosum* (Fr.) Bref.), що призводить до зниження їх продуктивності та стійкості. Разом із тим кількісна оцінка динаміки таксаційних показників у просторово-часовому вимірі та порівняльний аналіз фітосанітарного стану чистих і змішаних деревостанів на рекультивованих землях Шершнівського лісництва залишалися поза увагою дослідників.

Аналіз останніх досліджень і публікацій. Теоретичну основу лісової рекультивації закладено у працях П. С. Пастернака [10], Ф. М. Бровка [1] та В. П. Ландіна і М. М. Узлова [6]. Специфіку ґрунтових і лісорослинних умов Житомирщини висвітлено у роботах П. П. Надточія та Т. М. Мисливої [9], В. М. Турка [21]. Проблемі поширення *H. annosum* у штучних насадженнях присвячені дослідження М. М. Діденка [3] та А. Б. Марченка [7]. Роль змішаних насаджень у підвищенні біологічної стійкості обґрунтована в узагальнюючих роботах В. М. Маурера [8], Г. Т. Криницького [5], а також у міжнародних дослідженнях H. Pretzsch та ін. [20] і M. J. Kelty [17].

Зарубіжний досвід підтверджує перспективність сосни звичайної як піонерної породи для заліснення рекультивованих земель різного типу. За даними Z. Vacek та ін. [23], на рекультивованих вугільних кар’єрах, піщаних кар’єрах і дюнах запас біомаси 40–46-річних соснових культур лише на ~20% нижчий порівняно з природними лісами. Найвища продуктивність зафіксована на пострекультивованих вугільних кар’єрах – факт, що корелює з кращим хімічним складом субстрату. M. Pietrzykowski та ін. [18] встановили, що якість техногенних ґрунтів (вміст глини, насиченість основами, доступний фосфор, біологічна активність) пояснює більше 60% варіації індексу місцезростання сосни, що підкреслює визначальну роль едафічних умов для формування продуктивних деревостанів.

У дослідженнях на рекультивованих піщаних кар’єрах Південно-Східної Польщі встановлено, що механічна підготовка ґрунту та штучне створення лісових культур суттєво прискорює формування продуктивних соснових насаджень порівняно з пасивним заростанням [14]. Щодо фітосанітарного стану, M. Pietrzykowski та ін. [18] встановили, що 45-річні культури сосни на відвалах буровугільного розрізу можуть відноситись до категорії «здорових» з успішним природним поновленням понад 5000 шт./га. Проте на техногенно забруднених ділянках спостерігається пригнічення дерев, формування осередків шкідників та зниження біологічної стійкості насаджень [22]. На полігонах флотаційних відходів Zn-Pb коренева система сосни є мілкою (обмежена до ~60 см), що потенційно знижує стійкість деревостанів до вітровалів [19]. Ці міжнародні дані загалом підтверджують тенденції, встановлені для умов Шершнівського лісництва, і свідчать про універсальний характер виявлених закономірностей. Проте детальний аналіз динаміки таксаційних показників і фітосанітарного стану саме для насаджень на рекультивованих землях Шершнівського лісництва залишається недостатньо дослідженим.

Незважаючи на наявність загальних теоретичних розробок, питання фактичного стану, тривалої динаміки продуктивності та порівняльної стійкості чистих і змішаних соснових насаджень у специфічних умовах рекультивованих земель Шершнівського лісництва лишається недостатньо дослідженим. Відсутні також кількісні дані щодо зв’язку між породним складом деревостану та рівнем ураженості кореневою губкою для даного регіону, що обмежує науково обґрунтоване лісогосподарське планування.

Результати досліджень. Метою дослідження було охарактеризувати просторово-часову динаміку основних таксаційних показників лісових культур сосни звичайної на рекультивованих землях Шершнівського лісництва та встановити вплив породного складу деревостану на фітосанітарний стан насаджень, уражених кореневою губкою.

Об’єктами дослідження слугували лісові ділянки на рекультивованих землях Шершнівського лісництва Коростенського надлісництва Філії «Столичний лісовий офіс» ДП «Ліси України». Загальна площа лісових культур, створених починаючи з початку 70-х рр. XX ст. на землях, що вийшли з користування Іршанського гірничо-збагачувального комбінату, становить понад 583 га (9,9% від загальної площі лісництва 5914,3 га).

Для аналізу таксаційних показників опрацьовано матеріали чотирьох базових лісовпорядкувань (1977, 1987, 1997, 2017 рр.), охоплено 62 таксаційні виділи на площі 417,8 га, що становить 72% площ, де були створені лісові культури на рекультивованих землях [2]. Для вивчення фітосанітарного стану закладено три тимчасові пробні площі площею 0,2 га кожна у 52-річних насадженнях 39-го таксаційного кварталу (2025 р.). На пробних площах проводили суцільний перелік дерев з диференціацією за категоріями санітарного стану та класами Крафта. Індекс санітарного стану визначали за формулою [11]:

$$I_C = \frac{1}{N} \times \sum_{j=1}^{N} k_j \times n_j$$

де: I_C – показник стану; k_j – j-та категорія санітарного стану (від I до VI); n_j – кількість дерев у j-ій категорії санітарного стану; N – загальна кількість дерев на пробній площі.

Вміст гумусу визначали за методом І. В. Тюріна, реакцію ґрунтового розчину – потенціометричним методом у сольовій витяжці. Статистичну достовірність різниць між пробними площами перевіряли однофакторним дисперсійним аналізом (ANOVA).

За матеріалами лісовпорядкування встановлено, що цільовою породою при лісовій рекультивації була сосна звичайна (*Pinus sylvestris* L.), яка утворює 97,4% (403,5 га) вкритих лісовою рослинністю ділянок. Супутніми породами за схемою змішування (4рСз1рВч або 1рБп чи АкБ) виступали вільха чорна (*Alnus glutinosa* (L.) Gaertn.), береза повисла (*Betula pendula* Roth.) та акація біла (*Robinia pseudoacacia* L.). Детальний розподіл порід за площею і запасом наведено в таблиці 1.

Таблиця 1

Характеристика лісоутворюючих деревних порід на рекультивованих землях

Деревна порода	Площа, га	Частка, %	Загальний запас, м³	Запас, м³/га	Примітка
Акація біла (АКБ)	2,0	0,5	130	65	перестійна
Береза повисла (БП)	1,7	0,4	210	124	–
Вільха чорна (ВЛЧ)	10,6	2,5	1 200	113	–
Сосна звичайна (СЗ)	123,6	29,6	17 080	138	без осередків хвороби
Сосна звичайна, культури (СЗК)	279,9	67,0	40 660	145	в осередках кор. губки
Разом	**417,8**	**100,0**	**59 280**	–	–

Домінуюча частина насаджень (63,3%, 264,5 га) зростає у бідних борових (А) типах лісорослинних умов, субори (В) займають 33,8% (141,3 га). За режимом зволоження переважає свіжий гігротоп – 79,8%. Переважаючими типами лісу є A_2С (свіжий сосновий бір, 186,0 га) та B_2ДС (свіжий дубово-сосновий субір, 139,6 га).

За матеріалами чотирьох лісовпорядкувань встановлено, що насадження у перший ревізійний період (1977 р., 5-річний вік) зростали за ІІІ класом бонітету у сухому сосновому борі (A_1С) з повнотою деревостану 0,90. Вже у 1987 р. (15-річний вік) бонітет підвищився до І класу, повнота – 0,90. У 1997 р. (25-річний вік) зафіксовано формування свіжого дубово-соснового субору (B_2ДС), висоти деревостану 10–11 м та діаметра 12 см. Трансформація типу лісу із борового на субір свідчить про покращення едафічних умов унаслідок відновлення ґрунтотворних процесів. Станом на 2017 р. (45-річний вік) деревостани характеризуються висотою 15–17 м, діаметром 20–22 см, запасом 200–260 м³/га.

Розподіл насаджень за класами бонітету демонструє переважання найвищих значень: за І класом зростає 199,3 га (47,7%), за Іа – 72,3 га (17,3%), за ІІ – 112,1 га (26,8%). Середній клас бонітету становить І,1. Динаміку запасу за класами віку наведено в таблиці 2.

Таблиця 2

Розподіл лісових ділянок за класами віку та запасом деревостану

Клас віку	Площа класу віку, га	Запас класу віку, м³	Запас на 1 га, м³	Середня зміна запасу, м³/га в рік
ІІ	16,8	870	52	2,6
ІІІ	71,4	7 750	109	3,6
ІV	172,4	28 000	162	4,0
V	155,2	22 460	145	2,9
VI–VII	2,0	130	65	–
Разом	**417,8**	**59 210**	–	–

Аналіз таблиці 2 засвідчує зниження середньої зміни запасу від 4,0 м³/га в рік у IV класі віку до 2,9 м³/га в рік у V класі. Зменшення приросту на 27,5% у середньовікових насадженнях пов'язане з розвитком осередків кореневої губки та проведенням вибіркових санітарних рубок.

Дослідження фітосанітарного стану проводили у 52-річних насадженнях 39-го кварталу. Таксаційну характеристику трьох пробних площ наведено в таблиці 3.

Таблиця 3

Таксаційна характеристика деревостану на тимчасових пробних площах (вік 52 роки, 2025 р.)

№ пп	Номер виділу	Склад дерево-стану	Густота, шт/га	Висота, м	Діаметр, см	Бонітет	Повнота	Запас, м³/га	Серед. зміна запасу, м³/га
1	8	10Сз+Бп	890	21,7	22,2	І	0,64	274	5,2
2	9	10Сз+Бп	1000	20,5	22,0	І	0,71	305	5,9
3	14	9Сз1Акб+Бп	1030	25,6	22,8	Іа	0,75	320	6,1

На всіх трьох пробних площах виявлено ураження кореневою губкою. Однак за показниками розподілу дерев за категоріями санітарного стану та величиною індексу стану між ними зафіксовані статистично достовірні відмінності (таблиця 4).

Таблиця 4

Розподіл дерев сосни звичайної за категоріями санітарного стану та індекс стану

№ пп	I кат., %	II кат., %	III кат., %	IV кат., %	V кат., %	VI кат., %	Індекс стану	Ступінь ураженості
1	12,3	18,1	38,2	15,8	10,4	5,2	3,3	Середній
2	9,5	14,2	46,2	16,4	8,1	5,6	3,1	Середній
3	28,8	27,5	19,0	12,2	7,8	4,7	2,6	Послаблений

На пробній площі №1 (10Сз+Бп) найбільшою є частка дерев III категорії «дуже ослаблені» (38,2%), середній індекс стану – 3,3. На пробній площі №2 (10Сз+Бп) частка III категорії досягає максимального значення 46,2%, індекс стану –3,1. Принципово відрізняється ділянка №3 (9Сз1Акб+Бп) з підліском горобини звичайної: частки I та II категорій разом становлять 56,3%, сухостій – 12,5%, а індекс стану є найнижчим – 2,6. Достовірність різниць підтверджено дисперсійним аналізом: між площами №3 і №1 – Fф = 7,59 > F0,95 = 3,89 (P = 0,006); між площами №3 і №2 – Fф = 3,62 (P = 0,033) [21].

Аналіз розподілу дерев за класами Крафта на пробній площі №3 показав найвищу частку (72,6%) пануючих і співпануючих дерев (I–III класи), тоді як на площах №1 і №2 цей показник становить 53,6% та 51,7% відповідно. Висока частка відсталих у рості та всихаючих дерев на перших двох площах (IV+V класи – 47,2% та 48,3%) свідчить про прогресуючу деградацію монокультурних деревостанів.

Агрофізичні дослідження підтвердили зв'язок між часткою листяних порід у деревостані та родючістю ґрунту (таблиця 5).

Таблиця 5

Агрофізичні параметри ґрунту на тимчасових пробних площах (горизонт 0–20 см)

№	Склад деревостану	Густота, шт/га	Бонітет	Повнота	Запас, м³/га	Горизонт, см	Гумус, %	pH сол.
1	10Сз+Бп	890	I	0,64	274	0–20	1,32	4,5
2	10Сз+Бп	1000	I	0,71	305	0–20	1,35	4,7
3	9Сз1Акб+Бп	1030	Ia	0,75	320	0–20	1,50	4,8

На пробній площі №3 зі складом 9Сз1Акб+Бп вміст гумусу є вищим на 10–12% порівняно з площами №1 і №2 (1,50% проти 1,32–1,35%), а кислотність ґрунту є нижчою на 0,3–0,6 одиниць pH [13]. Це пов'язано з прискоренням деструкції лісової підстилки завдяки листяному опаду акації та горобини, що стимулює мікробіологічні процеси ґрунтоутворення [15, 16]. Усі ділянки відносяться до групи слабогумусованих (1–2%), що є закономірним для молодих рекультивованих ґрунтів.

Висновки та пропозиції

1. Лісові культури сосни звичайної, створені на рекультивованих землях Шершнівського лісництва, характеризуються стійкою позитивною динамікою таксаційних показників: за 40-річний період спостережень (1977–2017 рр.) бонітет підвищився з III до I–Ia класу, типи лісу трансформувалися з борових (A_1С, A_2С) у суборові (B_2ДС), а стовбурний запас у IV класі віку досяг 162 м³/га. Середній клас бонітету 62 таксаційних виділів складає I,1, що свідчить про успішне лісовідновлення і меліоративну роль лісових культур.

2. Провідною загрозою стабільності середньовікових насаджень є масове ураження кореневою губкою (*Heterobasidion annosum*): 67,0% площ соснових культур зосереджені в осередках хвороби. У IV–V класах віку середня зміна запасу знизилась від 4,0 до 2,9 м³/га в рік (на 27,5%), що є прямим наслідком патологічного відпаду.

3. Введення листяних порід (акації білої, берези повислої) до складу соснових насаджень статистично достовірно покращує фітосанітарний стан деревостанів. Індекс санітарного стану на ділянці складу 9Сз1Акб+Бп становить 2,6, що на 21–27% нижче порівняно з чистими сосняками (3,1–3,3). Продуктивність змішаних насаджень є вищою на 3,3–15,0% за запасом та середньою зміною запасу.

4. Агрофізичний аналіз підтвердив позитивний вплив листяних порід на родючість ґрунту: вміст гумусу у горизонті 0–20 см є вищим на 10–12%, а кислотність нижча на 0,3–0,6 pH-одиниці порівняно з чистими сосняками.

5. Виробництву рекомендовано: відмовитися від створення чистих монокультур сосни на рекультивованих землях; застосовувати змішані схеми з часткою акації білої або берези повислої не менше 10–20% у складі; своєчасно проводити вибіркові санітарно-оздоровчі рубки в осередках кореневої губки.

Література

1. Бровко Ф. М. Лісова рекультивація порушених земель : підручник. Київ : Вид. дім «Кондор», 2019. 320 с.

2. Геопортал [Електронний ресурс]. Режим доступу: http://forestry.org.ua/webtax/tax99/.

3. Діденко М. М. Поширення кореневої губки (*Heterobasidion annosum*) у похідних сосняках Полісся. *Наукові праці Лісівничої академії наук України*. 2014. Вип. 12. С. 145–149.

4. Зіборов С. М. Досвід заліснення відвалів титанових розсипів у Житомирському Поліссі. *Науковий вісник НЛТУ України*. 2018. Т. 28, № 5. С. 44–48.

5. Криницький Г. Т. Типологічні основи лісівництва : навч. посіб. Львів : НЛТУ України, 2010. 268 с.

6. Ландін В. П., Узлов М. М. Екологічні основи рекультивації земель у зоні діяльності гірничодобувних підприємств. Київ : Аграрна наука, 2010. 256 с.

7. Марченко А. Б. Санітарний стан соснових лісових культур на рекультивованих землях. *Біологічні системи*. 2019. Т. 11, Вип. 2. С. 210–215.

8. Маурер В. М. Теоретичні та технологічні засади відтворення лісів на засадах екологічно орієнтованого лісівництва. *Науковий вісник НУБіП України*. 2015. Вип. 219. С. 9–19.

9. Надточій П. П., Мислива Т. М. Оцінка придатності розкривних порід Іршанського гірничо-збагачувального комбінату для біологічної рекультивації. *Агроекологічний журнал.* 2011. № 2. С. 45–50.

10. Пастернак П. С. Лісова рекультивація земель. Київ : Урожай, 1990. 215 с.

11. Санітарні правила в лісах України : затв. постановою КМУ від 04.07.1995 р. № 555. 17 с.

12. Турко В. М. Особливості росту та продуктивності соснових насаджень на рекультивованих землях Іршанського родовища. *Лісівництво і агролісомеліорація*. Харків, 2010. Вип. 117. С. 132–138.

13. Турко В. М., Турко М. В. Зміна агрофізичних показників лісового ґрунту у лісових ділянках Шершнівського лісництва після лісової рекультивації на об’єктах гірничо-добувної діяльності. Лісові екосистеми: сучасні проблеми і перспективи досліджень – 2025 : матеріали IV Всеукр. наук.-практ. конф. Житомир : ПНУ, 2025. С. 96.

14. Aleksandrowicz-Trzcińska M., Drozdowski S., Wołczyk Z., Bielak K., Żybura H. Effects of Reforestation and Site Preparation Methods on Early Growth and Survival of Scots Pine (*Pinus sylvestris* L.) in South-Eastern Poland. *Forests*. 2017. Vol. 8. P. 421.

15. Chodak M., Niklińska M. The effect of different tree species on the chemical and microbial properties of reclaimed mine soils. *Biology and Fertility of Soils.* 2010. Vol. 46. P. 555–566.

16. Frouz J. Soil Biota and Ecosystem Development in Post Mining Sites. Boca Raton : CRC Press, 2013. 314 p.

17. Kelty M. J. The role of species mixtures in plantation forestry. *Forest Ecology and Management*. 2006. Vol. 233. P. 195–204.

18. Pietrzykowski M., Socha J., Doorn N. Scots pine (*Pinus sylvestris* L.) site index in relation to physico-chemical and biological properties in reclaimed mine soils. *New Forests*. 2015. Vol. 46. P. 2472013266.

19. Pietrzykowski M., Woś B., Pająk M., Likus-Cieślik J. Assessment of tree vitality of Scots pine root systems growing on reclaimed landfill waste after zinc and lead flotation. *Forest Research Papers.* 2017. Vol. 78. P. 3232013331.

20. Pretzsch H., del Río M., Ammer C. Mixed-Species Forests: *Ecology and Management.* Berlin : Springer, 2017. 653 p.

21. Turko V., Siruk Y., Turko M., Antonyukov O. Forest reclaiming in areas disturbed by mining and extraction of ilmenite deposits. *Sciences of Europe.* Praha. 2025. № 165. P. 3–8.

22. Vacek S., Vacek Z., Bílek L., Simon J., Remeš J., Hůnová I., Král’ J., Putalová T., Mikeska M. Structure, regeneration and growth of Scots pine stands with respect to changing climate and environmental pollution. *Silva Fennica*. 2016. Vol. 50 (4). Article 1564.

23. Vacek Z., Linda R., Cukor J., Vacek S., Šimůnek V., Gallo J., Vančura K. Scots pine (*Pinus sylvestris* L.), the suitable pioneer species for afforestation of reclamation sites? *Forest Ecology and Management*. 2021. Vol. 485. Article 118951.

ART STUDIES

TRANSFORMATION OF PSYCHOLOGICAL GOALS INTO PHYSICAL ACTIONS IN THEATRICAL ART

Seyidov T.
Senior lecturer of the department of "Theatre and cultural studies"
Nakhchivan State University, Azerbaijan
https://orcid.org/0009-0004-2960-8973
DOI: 10.5281/zenodo.19827642

ABSTRACT

The transformation of psychological objectives into physical actions constitutes one of the fundamental principles of acting in theatre art. This study examines the relationship between an actor's internal psychological processes and their external physical expression on stage. In theatrical performance, a character's inner world—comprising thoughts, emotions, and motivations—cannot be directly perceived by the audience (Ahmedova, 2025). Therefore, actors must convey these internal elements through purposeful physical actions such as gestures, movements, facial expressions, and vocal variations. The research highlights the significance of this principle within the framework of modern acting theory, particularly in the system developed by Konstantin Stanislavski. His method of physical actions emphasizes that every stage movement must serve a clear objective and reflect the character's inner logic. The study also explores how this principle enhances stage authenticity, strengthens the emotional connection between actor and audience, and contributes to the creation of believable and dynamic performances. Ultimately, the unity of psychological intention and physical action is essential for achieving artistic depth and realism in theatrical practice.

Keywords: Acting, Psychology, Movement, Performance, Realism.

Introduction

The art of theatre is a complex and multifaceted form of art based on the vivid and convincing expression of a person's inner world on stage. In this art, the actor is not merely a performer of a dramatic text, but also a creative individual who conveys the character's psychological state, thoughts, and emotional world to the audience.

For this reason, an actor must be able to transform psychological objectives into physical actions. In other words, the character's inner intentions must be expressed through concrete stage behavior. Once the actor understands what the character wants, they must demonstrate it on stage through various physical means such as movements, glances, gestures, changes in body plasticity, and variations in tone of voice. All these elements together clearly communicate the character's inner state to the audience.

One of the fundamental principles of acting in theatre theory is the transformation of psychological objectives into physical actions. Since the audience cannot directly observe the psychological processes occurring within the actor, these processes are expressed through visible behavior and movements on stage.

In theatre, a character's inner world is determined by their psychological objectives. A psychological objective shows what the character wants to achieve in a given situation and with what emotional or intellectual purpose they act. For example, a character may want to persuade someone, influence them, calm them down, or provoke anger. However, these psychological processes are not directly visible; the audience can only observe the actor's actions, gestures, and behavior.

For example, if a character wants to persuade someone, they may move closer, speak in a softer and calmer voice, and use convincing looks. If the character is angry, their movements may become harsher, their gestures sharper, and their tone of voice louder and more tense. In this way, the audience understands the character's inner feelings more through behavior than through words.

This approach is closely associated with the acting system developed by the Russian theatre theorist and director Konstantin Stanislavski. According to his system, an actor should not only feel the character's psychological state but must realize those feelings on stage through physical action. Properly chosen physical actions stimulate the actor's inner emotions and make the performance more realistic and convincing.

Stanislavski's "method of physical actions" requires that every movement an actor makes on stage serves a specific purpose. Every step, glance, gesture, or pause must be connected to the character's inner objective. This method helps the actor understand the character's internal logic and express it consistently, making the performance more vivid and natural.

The transformation of psychological objectives into physical actions is essential for achieving authenticity in acting. If an actor merely recites lines mechanically and their movements do not align with the character's inner state, the performance appears artificial. When the actor correctly understands the character's motives, their actions become logical and believable, ensuring the audience's trust.

In addition, the unity of psychological and physical action plays an important role in the actor's creative process. During rehearsals, the actor explores the character's inner objectives and experiments with different physical actions to find the most appropriate form of expression. This develops the actor's imagination and creative potential.

Throughout theatre history, many great actors have created unforgettable characters by skillfully applying this principle. Their performances create a

strong emotional connection with the audience and enhance the expressive power of theatre.

In conclusion, the transformation of psychological objectives into physical actions is one of the fundamental mechanisms of an actor's creative work. It allows the actor to express the character's inner world in a visible and understandable form. Through the unity of internal psychological processes and physical actions, vivid and convincing characters are created on stage.

Thus, a psychological state is transformed into a visible and perceptible form through physical action. This approach is closely associated with the acting system developed by the Russian theatre theorist and director Konstantin Stanislavski, who made a significant contribution to the scientific study of acting. According to his system, an actor should not be satisfied with merely experiencing the psychological state of a character but must realize those feelings on stage through physical action. Properly chosen physical actions stimulate the actor's inner emotions and make the performance more realistic and convincing.

Methodology

This study is based on a qualitative approach aimed at exploring the principle of transforming psychological objectives into physical actions in theatrical performance. The research focuses on understanding how actors apply this principle in practice and how it contributes to the creation of believable and expressive stage characters.

The primary method used in this research is theoretical analysis. Key concepts of acting theory, particularly those developed by Konstantin Stanislavski, are examined in order to define the relationship between a character's inner psychological processes and their external physical expression. Relevant literature on theatre theory, acting techniques, and performance studies is reviewed to establish a solid conceptual framework.

In addition to theoretical analysis, the study employs observational methods. Selected theatrical performances and rehearsal processes are analyzed to identify how actors translate psychological objectives into physical actions on stage (Gulkhara & Kamran, 2025). Attention is given to elements such as movement, gesture, facial expression, voice modulation, and stage behavior, all of which serve as indicators of internal psychological states.

Comparative analysis is also applied to evaluate differences between performances where this principle is effectively implemented and those where it is not. This allows for a clearer understanding of the impact of purposeful physical action on stage authenticity and audience perception.

Furthermore, elements of practical analysis are incorporated through the examination of rehearsal techniques. Exercises based on the "method of physical actions" are considered to understand how actors develop their roles and refine their performances. This includes exploring how actors experiment with various physical choices to express specific objectives.

Overall, this methodology combines theoretical, observational, and analytical approaches to provide a comprehensive understanding of how psychological objectives are transformed into physical actions in theatre, highlighting their importance in achieving realistic and compelling performances.

Results

Stanislavski's "method of physical actions" requires that every movement on stage serves a specific purpose. No action should be random; every step, glance, gesture, or pause must be directly connected to the character's inner objective. This method helps the actor understand the internal logic of the character and express it consistently, resulting in a performance that is vivid, natural, and convincing (Sadikhova, 2026).

The transformation of psychological objectives into physical actions is a key condition for achieving stage authenticity. If an actor merely delivers lines mechanically and their movements do not correspond to the character's inner state, the performance appears artificial. However, when the actor clearly understands the character's motives and objectives, their actions become logical and well-grounded, ensuring that the audience believes in what is happening on stage.

Moreover, the unity of psychological and physical actions plays an important role in the actor's creative process. During rehearsals, the actor explores the character's inner objectives, experiments with different physical actions, and seeks the most appropriate forms of expression. This process develops imagination, observational skills, and creative potential, allowing for a deeper understanding of the character.

In theatre, a character's behavior is determined by their psychological objectives, which define their goals, intentions, and emotional state. Although these internal processes are not directly visible, the audience perceives them through the actor's behavior. Therefore, every physical action—gesture, glance, movement, or pause—serves as a means of expressing the character's inner world.

As one of Stanislavski's followers, Boris Zakhava emphasized that when an actor's objective is concrete and vividly imagined, their actions become more active, attention more focused, and stage communication more dynamic.

The principle of transforming psychological objectives into physical actions holds a central place in theatre theory. It ensures that acting is not limited to the delivery of text but becomes a creative process in which internal experiences are expressed through purposeful physical behavior.

During rehearsals, this principle helps actors refine their performance by selecting actions that most accurately convey the character's psychological state. As a result, stage behavior becomes more precise, expressive, and believable.

Throughout theatre history, many great actors have created memorable performances by applying this principle. Their ability to connect every movement with inner intention strengthens the emotional bond between actor and audience.

In conclusion, the transformation of psychological objectives into physical actions is one of the fundamental mechanisms of acting. It enables the actor to present the character's inner world in a visible and understand-

able form. Through the unity of psychological processes and physical actions, performances become vivid, convincing, and artistically powerful.

Discussion

The transformation of psychological objectives into physical actions represents one of the central principles of modern acting theory. This concept emphasizes that an actor's internal experiences—thoughts, emotions, and intentions—must be communicated through visible and purposeful stage behavior. As argued by Konstantin Stanislavski, the actor's task is not simply to feel but to act in a way that makes those feelings perceptible to the audience (Stanislavski, 1936). This approach shifts the focus of acting from passive emotional experience to active, goal-oriented performance.

A key strength of this principle lies in its ability to create authenticity on stage. When actors base their performance on clearly defined psychological objectives, their physical actions become motivated and coherent. According to Stanislavski's "method of physical actions," every gesture, movement, and vocal change must serve a specific purpose connected to the character's inner life (Stanislavski, 1949). This ensures that performances are not mechanical but organically developed, enhancing believability and audience engagement.

Scholars such as Benedetti (1998) have further emphasized that the connection between inner intention and outer action is fundamental to realistic acting. Without this connection, performances risk appearing artificial, as actions lack psychological grounding. Similarly, Zakhava (1973) highlights that when an actor's objective is concrete and vividly imagined, their stage behavior becomes more dynamic and expressive, leading to stronger communication with scene partners and the audience.

However, the application of this principle requires significant skill and discipline. Actors must engage in a detailed process of analysis and rehearsal to identify objectives and experiment with appropriate physical actions. As Carnicke (2009) notes, this process involves both intellectual understanding and practical exploration, making acting a complex synthesis of theory and practice. Without sufficient training, actors may struggle to align their internal intentions with effective physical expression.

Moreover, this principle plays a crucial role in the rehearsal process. Through repeated experimentation, actors refine their choices and discover the most effective ways to embody their characters. This aligns with contemporary performance studies, which view acting as an iterative and exploratory practice (Zarrilli, 2002).

In conclusion, the transformation of psychological objectives into physical actions remains a foundational element of theatrical performance. It not only enhances realism and emotional impact but also provides actors with a structured method for developing their roles. By integrating inner experience with external expression, this principle continues to shape both actor training and performance practices in modern theatre (Sadikhova, 2025).

Conclusion

In conclusion, the transformation of psychological objectives into physical actions stands at the core of effective acting in theatre. It bridges the gap between a character's invisible inner life and the audience's visible experience on stage. Since spectators cannot directly perceive thoughts or emotions, the actor must embody them through purposeful movement, gesture, voice, and behavior. This process ensures that the character's intentions become clear, engaging, and believable.

The principles established by konstantin Stanislavski emphasize that authentic acting is not achieved through mechanical delivery of lines, but through the organic unity of inner experience and external expression. His "method of physical actions" demonstrates that every movement on stage must arise from a clear objective and serve a dramatic purpose. When actors fully understand their character's motivations and translate them into concrete actions, their performances gain depth, coherence, and emotional truth.

Moreover, this approach plays a vital role in the actor's creative development. Through rehearsal and exploration, actors refine their ability to connect psychological intention with physical expression, strengthening their imagination, discipline, and stage presence. This not only enhances individual performances but also contributes to the overall impact of theatrical art (Sadikhova & Babayev, 2025).

Ultimately, the transformation of psychological objectives into physical actions allows theatre to fulfill its expressive potential. It creates a powerful connection between actor and audience, where inner human experiences are communicated in a tangible and compelling way. As a result, this principle remains one of the most essential foundations of modern acting and theatrical practice.

References

1. Ahmedova, G. (2025). Theatrical Structures and Performance Traditions in Azerbaijani Folklore. *EuroGlobal Journal of Linguistics and Language Education*, *2*(3), 74-82.

2. Benedetti, J. (1998). *Stanislavski: An Introduction*. London: Methuen Drama.

3. Boris Zakhava, The Art of the Actor and Director. Baku: Maarif Publishing House, 1984.

4. Carnicke, S. M. (2009). *Stanislavsky in Focus: An Acting Master for the Twenty-First Century* (2nd ed.). London: Routledge.

5. Gulkhara, A., & Kamran, G. (2025). The Role of Translation of Scene Language in Intercultural Communication. *Porta Universorum*, *1*(7), 104-113.

6. Hapgood. New York: Theatre Arts Books, 1936

7. Jerzy Grotowski, Towards a Poor Theatre. New York: Routledge, 1968.

8. Konstantin Stanislavski, An Actor Prepares. Translated by Elizabeth Reynolds.

9. Konstantin Stanislavski, Building a Character. New York: Theatre Arts Books, 1949.

10. Konstantin Stanislavski, Creating a Role. New York: Theatre Arts Books, 1961.

11. Michael Chekhov, To the Actor. New York: Harper & Row, 1953.

12. Peter Brook, The Empty Space. London: Penguin Books, 1968.

13. Sadikhova, S., & Babayev, J. (2025). Linguistic analysis of art terms in English. *Porta Universorum*, *1*(3), 214-223.

14. Sadikhova, S. (2025). XIX Century World Fine Arts: From Classicism to Modernism. *Porta Universorum*, *1*(8), 106-115.

15. Sadikhova, S. (2026). Neural networks as artists: Exploring AI in contemporary painting. *Acta Globalis Humanitatis et Linguarum*, *3*(1), 150-168.

16. Sanford Meisner and Dennis Longwell, Sanford Meisner on Acting. New York: Vintage Books, 1987.

17. Uta Hagen, Respect for Acting. New York: Wiley, 1973.

18. Vsevolod Meyerhold, Meyerhold on Theatre. London: Methuen, 1969.

19. Zarrilli, P. (2002). *Acting (Re)Considered: A Theoretical and Practical Guide* (2nd ed.). London: Routledge.

THE DEVELOPMENT OF A MUSICAL THEATER ACTOR'S VOICE

Zhusip D.
Honored Artist of Kazakhstan,
Associate Professor at the Academy
of Arts. Temirbek Zhurgenov
Medetkyzy N.
1st year master's student at the Academy
of Arts. Temirbek Zhurgenov
Sultanova A.
Master of Pedagogical Sciences,
Lecturer at the Temirbek Zhurgenov
Kazakh National Academy of Arts
DOI: 10.5281/zenodo.19827694

АННОТАЦИЯ
В этой статье рассматривается важность голос актера музыкального театра.
ABSTRACT
This article discusses the importance of a musical theater actor's voice.
Ключевые слова: Актерское мастерство, действие слова, характер, образ, жест, режиссер, спектакль.
Keywords*:* Acting, word action, character, image, gesture, director, performance.

Action is divided into two types: activity — that is, the subject's spontaneous (independent, free) influence on objective reality — and reaction, that is, activity arising from the influence of objective reality upon the subject. Objective reality, as we can see, must be present in both cases; without it, no activity is possible. However, its mere objective existence is insufficient — the subject must experience it in some way. This lived experience of objective reality is referred to as verbal action. Thus, verbal action in the process of reading a literary text and revealing its stylistic nature constitutes the essence and significance of the actor's continuous professional life or "experience" in creating a stage image. Verbal action is a deep and multifaceted psychological process that depends on the individual characteristics of each artist, especially the actor. It is no coincidence that the fundamental views of the great theorist of acting Konstantin Stanislavski and the distinguished Kazakh theatre scholar Mukhtar Baiserkenev coincide regarding verbal action in the process of reading a text; each sought to profoundly explain its importance in the creation of a stage image. Verbal action in reading a literary text represents a holistic reflection of objective reality that arises from the direct impact of real-world objects upon the human senses. It includes perceiving the object as a whole, differentiating its individual features, selecting informational content relevant to the purpose of action, and forming a sensory image. Verbal action is connected with thinking, memory, and attention, and it becomes integrated into practical activity and communication processes. At the end of the nineteenth century, theatre was closely associated with its own repertoire and with sketch-like plays depicting ready-made facts lying on the surface of life. The lack of thematic depth and authenticity was concealed behind external plausibility and carefully accumulated everyday details. Plays of this period confined actors within superficial life characteristics, encouraging external typification and imitation of speech that emphasized formal traits of character, worldview, or nationality. The "truth" of such theatre was theatricalized; its realism and stage expressiveness were distinguished by conventional speech and memorized vocal modulation. Traditional methods of expressing emotion, along with codified gestures and tonal patterns, were transmitted from generation to generation. Great artists, through the force of their talent, broke free from outdated clichés and demonstrated models of passion, vitality, experience, and naturalness. They revealed the living breath of truth and power that served the realization and disclosure of real life. However, in the speech practices of Russian theatre — even during the formation and flourishing of realist art marked by the names of Mikhail Shchepkin, Alexander Ostrovsky, Pavel Mochalov, Maria Yermolova, Mikhail Sadovsky, and Alexander Lensky — by the end of the nineteenth century clearly defined formal clichés had nevertheless emerged. This indicated the lag of art behind the demands and needs of living reality. The intonational techniques of stage speech increasingly entered into deep contradiction with the evolving artistic tasks facing twentieth-century theatre, which sought to respond to the demands of its time and to rethink its expressive means accordingly. As Anatoly Lobanov rightly observed: "There was truth in the Maly Theatre. Let us say Gogol appeared and spoke his truth — and suddenly it became unbearable to listen to people on stage speaking in the pre-Gogolian manner. The Art Theatre arrived and proposed a different rhythm and manner of speaking in life, and beside it the speech style of the Maly Theatre began to seem, so to speak, an anachronism." Declamation, pathos, and theatrical "stamps," along with everyday conventional markers, became obstacles to the development of theatrical art. A refined theatrical consciousness once again intensified its demand for truth in stage speech — truth corresponding to contemporary life, to its needs, anxieties, and emotional experiences, and to the authenticity of life on stage. At the end of the nineteenth century, the Music and Drama School of the Philharmonic Society played

a special role in shaping new approaches to actor training. Within its walls, in 1891, at the special invitation of Alexander Yuzhin, Vladimir Nemirovich-Danchenko began teaching dramatic art to actors. Nemirovich-Danchenko worked at the school with great enthusiasm and dedication for more than a decade, until 1901. During this time, he trained several generations of actors, including such major theatre figures as Olga Knipper, Ivan Moskvin, Vsevolod Meyerhold, Nina Litovtseva, Maria Savitskaya, and Sofia Khalyutina. His pedagogical activity at the Philharmonic School possessed immense and transformative significance for the Russian theatre school. During these years, his creative method took shape, as well as his approach to resolving the fundamental artistic and methodological issues involved in training an actor of high culture, genuine stage truth, and elevated civic consciousness. Nemirovich-Danchenko regarded theatrical pedagogy as an entirely new approach to actor training and as a means of creating a new theatre. As a playwright, writer, director, and public figure, he formulated the tasks of "initiating into art" as follows: "To preserve individuality, to bring a 'spark' into life, to assist its development, to work constantly with human material, to saturate it with one's best ideas — this is the seed of theatre, its deepest and most captivating essence…" Before Nemirovich-Danchenko's arrival at the Philharmonic School, instruction in theatrical creativity was far from satisfactory. He later recalled: "The educational significance of the theatre school was completely disregarded; it was impossible to convince anyone of the importance of voice production, diction, flexibility, dance, fencing, and general educational courses." The traditions of great actors had been forgotten, and no systematic training existed. Pedagogy was limited to preparing roles and developing techniques for expressing emotions. The pedagogical position closest to Nemirovich-Danchenko's principles and demands was that of Alexander Lensky, who worked with rare dedication at the Maly Theatre School. Nemirovich-Danchenko and Lensky, discussing both general and specific issues of theatrical pedagogy in detail, sought to share their explorations, experiments, and achievements with one another. With exceptional persistence, Nemirovich-Danchenko searched for methods and means to combat the inertia of theatrical art and pedagogy, as well as routine formulas and clichés. He criticized the theatre school for deriving not from life, but from stage stereotypes — for teaching the depiction of external aspects of life, the repetition of emotional schemes, and the memorization of theatrical clichés. Therefore, he insisted with particular force on the radical restructuring of the system of theatrical education. Nemirovich-Danchenko rejected the old practice of preparing roles; he denied technology for technology's sake, and reading for reading's sake. He sought ways to educate an artist capable of living on stage, of revealing the character of an image, of sensing truth, and of thinking and creating independently. As he wrote: "Above all, I seek authenticity and a serious artistic foundation. The professor's task is to teach students to think about the characters they portray and to show them how a role should be perceived." Even at that time, Vladimir Nemirovich-Danchenko believed that in order to free the actor's art from falsehood and cliché, simple and truthful speech was essential. A considerable part of his pedagogical work was therefore devoted to cultivating the actor's speech — its expressiveness, brightness, and simplicity, as well as its clarity and richness. This can be observed in the detailed substantiations of his teaching program, in his requirements concerning "tone" and diction, and in his notes on individual students, where he consistently evaluated their data and achievements from the standpoint of stage speech: "Knipper: noble diction, honest tone, very intelligent declamation. Savitskaya: tone clear in the sense of sincerity and beauty, not entirely precise, yet free from vulgarity and coarseness." In his work on tone, Nemirovich-Danchenko paid particular attention to such concepts as artistic taste, vitality, simplicity, lightness, richness of imagination, verbal action, the раскрытие stylistic nature of the text, correct understanding of the role, and perceptiveness. In his work on diction, he emphasized the voice, the beauty and strength of sound, the ability to command it, purity and clarity of articulation, authenticity, and variety of intonation. In working with the word, he demanded not merely technical excellence in pronunciation, but above all the naturalness and vitality of speech, the accurate transmission of thoughts, feelings, and moods grounded in comprehensive analysis of the material and deep psychological interpretation of its content, as well as the revelation of the stylistic nature of the text. We find confirmation of this in his directorial practice, for example in his production plan for Julius Caesar (referring to the staging of Shakespeare's tragedy). Nemirovich-Danchenko focused closely on the logical structure of the text. He carefully analyzed the semantic and intonational character of each phrase in Brutus's monologue, relating it to the character's personality, actions, objectives, and thoughts. By answering questions such as, "Why does the character speak in this way at this very moment, and not differently?", he took decisive steps toward understanding verbal action through uncovering the stylistic nature of the text. Not only professional training, but also the comprehensive cultivation of the actor's personality constituted the essence of his pedagogy. This marked a new stage and a significant advance in theatrical education. In the struggle for a new theatre that reflected life — for social and artistic truth, and for a new type of actor — the struggle for the living, active word occupied a special place. "The old template had to be broken… In order to free ourselves from the conventional mastery of transmitting stage experience… it was necessary to shake off the entire shell of conventions in intonation and vocal modulation, to achieve the highest simplicity of theatrical speech, yet without rendering it dull, pale, or colorless, and without depriving it of lyrical shading. The simplicity of verbal action does not mean excessively simplified speech as in everyday life." Understanding stage speech as a mode of being and communication became one of the most important aspects of the new theatre's aesthetics. Naturally, this development was made possible by new dramaturgy. Above all, one may mention the plays of Anton Chekhov, although his works were not staged at

either the Alexandrinsky Theatre or the Maly Theatre at first. The renewal of dramaturgy, striving to reveal the depth and substance of life, was directly connected with progressive literature. The dramatic novel of Fyodor Dostoevsky, the dramaturgy of Leo Tolstoy, and the plays of Chekhov — all sought to portray the human being in the full complexity of spiritual life. They revealed not only objective connections expressed in textual structure, but also deeper additional meanings and the stylistic nature of the text. From the understanding of subtext arose verbal action. From their very first attempts to create a new theatre, Konstantin Stanislavski and Nemirovich-Danchenko showed a deliberate and profound interest in theatrical speech traditions. Stanislavski singled out Pavel Mochalov from the entire theatrical world rich in talent as a genius who addressed epoch-making problems. His aspiration toward genuine experience, the unexpectedness and spontaneity of verbal action, the naturalness of speech, his capacity to reveal inner life and the stylistic nature of the text — more than the declamatory manner of the old romantic school or the deliberately exaggerated everyday speech obscured by an impenetrable shell — deeply convinced audiences and attracted the emerging new theatre. The formation of the artistic method of the Moscow Art Theatre was characterized by reflection on the living word, by the search for ways to achieve the highest simplicity of speech, and by a complete rejection of traditionally canonized stage verbal action. In the search for the "truth of feeling in given circumstances," the theatre sought a new, contemporary manner of speech. However, the revolution in stage speech was not only about rejecting everyday similarities, old speech canons, or the usual conventions; it was also about the very idea of creating truth in stage interactions instead of using literal words. Behind the text lay the world of thoughts, viewpoints, and emotions that underlie human behavior and give rise to words in life, as well as its stylistic nature. The emphasis on inner action and inner life, rather than the external, revealed the causes and connections of thoughts and words, generated their flow, and brought to light the inner forces that determine the life of speech, reflecting a desire to uncover the text's stylistic nature. This idea was manifested in the 1898 production of The Seagull. Everything in the play served to reveal this inner life: the free mise-en-scène that obeyed no tradition, the flow of life continuing behind the stage, the sound of rain, immersing the characters in their everyday worries, distant emotions, and sudden pauses. The manner of speech in the performance was new because theatrical, conventional, elevated speech disappeared. The liveliness and authenticity of speech arose not from external signs of reality, but from the truthfulness of behavior, understanding the thoughts, and grasping the stylistic nature of the text. The laws of reading a stage text had long been known, but they did not apply in the new theatrical processes. This does not mean that simple and vital speech laws did not exist. On the contrary, "the ability to speak simply and beautifully is a science with its own rules." But the theater did not know these rules. They had to be carefully studied and mastered. The entire creative practice of the founders of artistic theater was connected with discovering the true organic laws of living speech on stage. Theater specialists understood that one should not "act" any emotion, mood, stance, word, style, or image; instead, the stylistic nature of the text had to be revealed and realized through the effectiveness of speech. Behind the protest against artificial speech was always respect for the author's word and the desire to convey it to the audience accurately and convincingly. Yet while valuing the word, just as an artist judges its color and tone, or a musician evaluates sound, the founders of the new theater considered it an unchangeable truth: the actor's word had to exist on the same level as all elements of the creative process, arising naturally, organically, as a direct result of inner life. The theater persistently sought methods to work with speech that would correspond to the entire actor's system. Adapting speech for direct stage expression was a completely different process. The idea of returning to The Seagull arose to draw the actor's attention to particular details: "a match and a burning cigarette in the dark, powder in Arkadina's pocket, Sorin's blanket, a comb, a cuff, washing hands, drinking water, and so on… The actor had to be trained to perform these actions so that speech would become easier." Sometimes the striving to make speech lifelike and natural stemmed from a heightened interest in speech characteristics, where speech became a means for the theater to create the truthfulness of the character's behavior. This led to ethnographic precision in paying attention to speech features and details in texts such as L. Tolstoy's The Power of Darkness and M. Gorky's The Lower Depths, and in capturing the stylistic nature of the text. Yet for theater directors, the most crucial adaptation for living speech appeared to be the actor's organic life activity. K. S. Stanislavski, reflecting on the production of L. Andreyev's The Life Drama, wrote in the chapter "Revealing Familiar Truths" that he had kept actors away from rigid mise-en-scène decisions. Stanislavski feared that mise-en-scène could distort the inner process, conceal it, push it into the background, or even replace living behavior with "muscle memory." Therefore, he "eliminated the mise-en-scène." In 1909, Stanislavski staged I. Turgenev's A Month in the Country using a strictly static approach. M. V. Dobuzhinsky's remarkable set design, with its enclosed depth, symmetrical stage images, and carefully indicated transitional passages, was cut away. All the director's attention was focused on the inner process. His detailed commentary revealed what lay behind each line, what performers should feel and understand. At that time, the principle he called "illumination" was extremely important: a sequence of actor tasks, based on careful analysis, ensured physical comfort and revealed the subtext of speech. In Stanislavski's directorial notes, there is clear and general guidance showing that the content and stylistic nature of the text is revealed through subtext, which produces the effectiveness of speech. In the second act of this play, the text reads: Natalya Petrovna: "No, please, do not shoot toward the garden. Save this poor bird… Moreover, you will startle your grandmother." K. S. Stanislavski (p. 19) noted: "These words should not be understood literally; the point is that there seems to be an additional meaning or

subtext in them, like 'I love you,' 'I want to be with you.'" His directorial notes also contain purely technical instructions: "speaks loudly" (p. 24), "the speech manner and tone of the teacher, that is, a lady of the style of that time" (p. 30), "silent, as if hiding from others" (p. 35), "speaks very simply and quietly" (p. 35), "I am in love, simply, slowly, as if reading the letters of this feeling" (p. 36), "at a fast pace" (p. 37). These instructions are few, and all are aimed at revealing subtext, the stylistic nature of the text, how to convey it to the audience, how to express the effectiveness of speech, to enhance and refine physical well-being, and to adapt performance organically. Vladimir Ivanovich Nemirovich-Danchenko and K. S. Stanislavski understood that seeking the life truth of a word, uncovering the stylistic nature of a text, and achieving it were not easy tasks. Even though Stanislavski disliked the study process when working on A. P. Chekhov's plays, he engaged extensively with hexameter. The actor's vocal capabilities—their beauty, clarity, and sound potential—were important for Nemirovich-Danchenko in addressing purely creative challenges. At the Moscow Art Theatre's stage, in the premiere of Three Sisters, the role of Olga was performed by the highly captivating actress M. G. Savitskaya. Savitskaya, with her uniquely beautiful voice that had once started with Antigone, played the elderly daughter with heartfelt delicacy. Her beautiful voice allowed Nemirovich-Danchenko to perceive the poetic nuance needed to convey Chekhov's language and the stylistic simplicity inherent in the author's text. After Savitskaya passed away, the actress O. Butova aspired to play Olga. Despite recognizing Butova's abilities and talent, Nemirovich-Danchenko did not deem it appropriate to assign her this role. In a letter to Shchepkina, Butova admitted: "Nemirovich-Danchenko spoke wonderfully. He said everything that could be said to an actress, but overall, portraying Olga is not my task; he said my talent is limited… My voice is my greatest obstacle." From production to production, from role to role, Nemirovich-Danchenko's advice, his notes on speech manner and nature, and guidance on "finding the character's speech" accumulated. In a letter to M. S. Stanislavski (1902), discussing the role of Satin in M. Gorky's The Lower Depths, Nemirovich-Danchenko emphasized the need to develop a new technique: "Develop rapid, effortless speech without pauses. Words must flow from your mouth easily and continuously." After the Great October Socialist Revolution, an integrated approach emerged in the creative practice of the Moscow Art Theatre: speech was considered the most important component of a performance; stage speech became an internally managed process dependent on the speaker's objectives, circumstances, relationships, individual characteristics, and psychophysical condition. M. O. Knebel recalled: "To create a living character, generate the effectiveness of speech, and reveal the stylistic nature of the text, actors needed versatile, varied, and expressive speech. This was an essential condition for working on the production." The living soul of a phrase is sensed internally but expressed with taste. Work on subtext and acting technique are closely interconnected. Choosing breath, lightness, subtlety, rhythm, and the expressiveness of sound requires developing vocal technique and mastery, while simultaneously uncovering the effectiveness of speech and the stylistic nature of the text in the creative process and reading. By the late 1930s, Nemirovich-Danchenko's key methodological principle was clearly articulated: "A word arises from the seed of the actor's psychophysical character in the role." He explained this inner connection as follows: "An actor achieves the right path in creating a stage image by understanding the thinking, character, and stylistic nature of the text of the character he or she embodies. From this, movement qualities and speech manner, as well as the effectiveness of speech, naturally arise." While working on Three Sisters, Nemirovich-Danchenko consistently returned to the idea of emotional ignition and the actor's physical well-being. To give birth to a word, one must "plant the emotional seed," and for this, all behavior, thoughts, and feelings must adapt to the stage situation, giving rise to the effectiveness of speech. "This was the most important aspect for me during preparation," he said. An actor's mood develops from understanding the typical traits, complexities, and contradictions of the characters in the play, their relationships with people, their individual characteristics, life experiences, profession, biography, and the unity of their personal qualities. Nemirovich-Danchenko moved from the character, lifestyle, thought, temperament, and physical and behavioral state to the actor's speech. "Begin to imagine what he is like. Perhaps your speed of speech is too fast for Chebutykin? He is slow, filled with life experience, and therefore cannot speak quickly" (Gribov – Chebutykin).

"When Olga walks around the room, she communicates all of this" (p. 51, 181) (Elanskaya – Olga). He further instructed Elanskaya: "Olga is the eldest in the house; she is not sentimental, but impressive; she is the future head of the gymnasium; she speaks clearly… One must endure such simplicity to speak more precisely…" To Georgievskaya – Natasha: "…because there is coldness in her inner world… therefore she speaks firmly, harshly, and with authority." We will not continue with examples, but we note the ideas of Nemirovich-Danchenko and Stanislavski: their thoughts deeply connect all aspects of speech with a person's individuality, personal and emotional traits, and are among the most important and forward-looking from the perspective of understanding the laws of modern speech communication. The development of speech art in the Soviet theater was based on strengthening the realist traditions of the actor's school and on cultivating civic consciousness and the social significance of theater. Before the Great Patriotic War, Soviet theater was distinguished by highly professional mastery of stage speech. Its traditions were shaped under the influence of the classical Russian school of speech, while creative approaches were renewed through Soviet theater practice. The culture of theatrical speech was enriched with sounds, rhythms, shades of socialist reality, intonations, expressiveness, and the style of Soviet dramaturgy. An important factor in the formation of the Soviet school of speech was the creative influence of the leading Soviet directorial trend: for example, the work of A. I. Dikiy, A. D. Popov, N. P. Okhlopkov, A. M. Lobanov,

and Yu. A. Zavadsky. Alongside K. S. Stanislavski, who considered the enactment of the word on stage—that is, speech effectiveness and revealing the stylistic nature of the text—as a crucial element, Vladimir Ivanovich Nemirovich-Danchenko's influence was also significant. For actors in the 1920s–1940s, speech and voice were the primary focus. Actors such as B. V. Shchukin, M. F. Astangov, M. I. Babanov, and N. M. Mordvinov stood out for their exceptional voices, intelligent, free, and expressive speech, nuanced articulation, and musicality. Beyond this, behind each word there lay a real, bold, and confident contemporary feeling, deeply and passionately engaged with the purpose at hand. The brightness and fullness of the voice, the expressiveness of diction, the clarity and scale of speech, its carefully considered and confident expressiveness, unique personal intonation, dynamic range, and tempo-rhythm—all these were distinctive features of Moscow Art Theatre actors' manner of speech. The actors' speech created a special atmosphere imbued with the breath of stage reality. Yet this was not only the actor's truth; it was also a purified, stylized, and heightened truth born from adherence to the author's manner, an expressive and image-based reality. During the Soviet period, Nemirovich-Danchenko's directorial work crystallized the principles of creating living speech on stage. Plays, requiring a synthesis of life, social, and theatrical truths, demanded the director's most engaged and exacting work with the word. The specificity and truth of stage speech for Nemirovich-Danchenko lay first and foremost in precisely understanding and clarifying the author's style. How the author's idea should be expressed, and by what expressive means it could be conveyed, was equally important: "…you only use the author's idea, subordinating their vocabulary to everyday speech. The author's individual intonation always lives in a good play… If we do not hear it, we cease to have the 'author's theater.' Then we limit ourselves to content alone, neglecting expressive complexity. Then it no longer matters how it is written, and creativity, art, stops. This leads to a general decline in the theater. Only a 'general simplicity' remains." Everyday, life-like speech, in the works of A. Ostrovsky, M. Gorky, A. Chekhov, L. Leonov, and N. Pogodin, was sublimated behind the text, in the author's style and in the actor's speech, through the expressive plasticity of words, tonal relief, boldness and clarity of intonation, and rhythmic articulation. Actors complemented and revealed the speech traits of the environment provided by the author, carefully and lovingly using pronunciation, dialect, emphasis, and individual speech characteristics. Naturalness was combined with remarkable expressiveness, musicality, purity, fullness, and variety. Their speech reflected the requirements of the time: its aesthetics, rhythm, and orthoepic and phonetic culture. The best Soviet actors of the 1920s–1940s were exceptional in both individuality and manner of expression, collectively representing the speech art of their era. K. S. Stanislavski and Nemirovich-Danchenko, defining ways to create life on stage, developed an approach to living stage speech based on the effectiveness of words, grounded in the precise alignment of actions, imagination, and stage tasks, and in absolutely exact communicative means. Stanislavski's system began forming before the revolution (at least from 1907), rooted in early theatrical experiments. Yet it was during the Soviet era, when its guiding principles were articulated and by the 1930s, that the Stanislavski system solidified as a creative method of Soviet theater. Like any living phenomenon, it developed and evolved through the theater's life experience and specific creative conditions. If the foundation of this system is a super-task, the theory of action, and stable values, if the ways to create "the life of the human spirit" and the actor's lived experience serve as an objective method of creativity, then expressiveness, external technique, and representational methods are naturally flexible and changeable. The measure of truth, realism of stage speech, and the culture of speech are determined by contemporary reality, its requirements, norms, and aesthetic and ideological standards. The fundamental rupture in the tradition of stage speech before the war was marked by the Great Patriotic War, which transformed the entire life of theater and decisively affected stage speech. Humanity went through suffering and heroic trials; the meaning of tragedy was revealed sharply and harshly, and spiritual values were expressed with unprecedented intensity and power. Understanding humanity's place in the postwar world required civic maturity and natural authenticity in depicting life, abandoning embellishment of human relationships. Traditional forms of external acting technique hindered performance: imitation, preprepared intonation, memorized pauses and emphases were increasingly felt, becoming standardized for decades, and thereby often disrupting the living processes of truth. The general accepted tradition of theatrical speech declined in representing the essence of life phenomena in the best postwar Soviet plays. Artists seeking a new aesthetic ideal found in theater, behind simple exterior speech, the concrete, everyday matters that revealed the inner life of characters. Of course, this was speech that served "only itself"; understanding its content and the inner life of existence on stage could occur only under high creative conditions, when directors and actors could reveal deep, living processes. At that time, in Sovremennik theater productions, real life was conveyed on stage clearly and sincerely. The everyday similarity of intonation in G. A. Tovstonogov's bold directorial decisions created high tension in events, while the truth of feelings and thoughts in A. V. Efros's productions was lived and performed authentically by remarkable actors. The experience of young Sovremennik actors, born within the walls of the Moscow Art Theatre and its school, embodied the realism of the Moscow Art Theatre, the immediacy and authenticity of contemporary relationships, and a thirst to speak in a living, modern language reflecting the realities of the time. In creating a new theater, O. N. Efremov had to address the full range of civic, human, and artistic concerns. Solving these issues required a new drama that could depict the people's new life experience, in which young actors could portray the destinies and lives of their contemporaries and peers deeply and fully. Perhaps for this reason, V. Rozov's Forever Alive became one of the theater's most compelling, daring, and authentic productions. Themes of war, life, love, loyalty, and

selflessness were presented in a way that was heartfelt, relevant, and innovative. Young actors approached each performance as a personal struggle. They lived through their characters' lives and were infinitely truthful. The vivid structure and stylistics of Rozov's highly cultured play found expression in the everyday reality of life and in the authenticity of the actors' speech. Stage speech held a unique place in the aesthetics of the new theater. By setting clear artistic goals, Efremov taught actors the skill of conveying the final objective through the unfolding of each role. Emerging from living, active stage behavior, actors explored how each character would conduct themselves relative to the pressing purpose of the performance. The question "Why?" was never abandoned throughout the role work. Secondary but fully realized truths—the emotional precision of inner life, the absolute reliability of movement and gesture—all began with, and gained momentum from, the word. Speech on stage was neutral in phonetic and stylistic qualities. This was reinforced by the author's everyday vocabulary and the credible ordinariness of the play's characters. The actors of the Moscow Art Theatre were trained in drama, and its style and imagery significantly shaped the theater's manner of speech. Questions of speech distinctiveness and speech characterization revealed the personal traits of character and role, playing a major role in their work. For the actors in Efremov's theater, most of whom were portraying their contemporaries, the role was above all the "I" of a person placed in an unfamiliar situation. Efremov developed actors' abilities through large, cohesive episodes, moving through entire segments of a role toward the central objective. In semantically concentrated episodes, speech could carry weight and significance, with the word taking precedence. In Rozov's Forever Alive, the theater's manner of speech appeared credible and vivid. For example, Veronica (A. B. Pokrovskaya) runs into the room hopelessly and flustered, grabbing tables, chairs, and cabinets, as if seeking a support to rescue. From the torrent of grief carrying Veronica, only the essential words emerge, held as if by someone drowning in water. In the speech of the best actors of the 1950s–1960s, words were delivered in a new, living manner, growing from a deep interplay of elements. However, the power that came from the truth—its resemblance to reality, intellectual assimilation, and precision of action—could, if reduced to mechanical replication, immediately turn against itself. This is a natural occurrence. Everyday speech, as in life, conveys no meaningful process, yet in imitation it easily takes root and creates the illusion of truth. The desire to remove layers of resemblance and habit sought to cleanse stage speech and acting skills from clichés, to search for new, even deeper ways to depict life on stage. Yet in seeking living speech, while avoiding theatrically stylized pronunciation, only the superficial features of everyday speech developed: displayed words, quiet speech, "under-delivered," calm, monotonous, "non-actor" voices, slow articulation, incompleteness, and gaps in sound. A whole recent period of theater practice became closely associated with "whispering realism," self-serving expression, and mannerless, dim, indistinct, theatricalized sentences. Many qualities of theatrical speech came to be labeled as mere theatricality. Well-prepared voices, polished speech, carefully measured sentences based on grammatical logic, exact pauses, speech accents, rising and falling intonation—all hid uncertain, artificial, lifeless content. If declamation was the hallmark against which early 20th-century fine theater fought, by mid-century the hallmark had become quiet, gray, and muted speech. This conventionalized, external, imitative method, canonized as part of acting technique, led to a crisis in the art of stage speech and affected the most important and profound inner qualities of acting. This phenomenon, often considered speech neutrality, reflected a significant decline in the theater's speech culture. "There are now two extreme situations regarding the word," wrote G. A. Tovstonogov. "On one hand, the pursuit of a modern approach to being on stage, realism, and fighting declamation has led to neglecting theatrical speech through deliberate word play. This undermines the nature of our art… There is another old problem. This is the actor turning the word into a self-sufficient element, after which the effective process stops, and speech begins in isolation. In this case, the nature of theater is also disrupted." In searching for a new, living, and more organic way for the actor to Inhabit a role—regardless of approach—if it is aimed at deepening our ideas about life truth on stage, the word is placed in the foreground. In other words, all the subtlety of experience is represented and rendered visible. If the rejection of the word is merely an attempt to mimic contemporary life, the very meaning of theater disappears. Unfortunately, the formal methodology of creating everyday-like word effectiveness, speech, and whispering became commonplace. Directors' primitiveness, the inability to translate the super-task into action, and the neglect of the expressive potential of the author's language often led to imitation of the worst examples of poor, quotidian speech, rather than portraying vitality authentically and integrating it with speech and stage realism. Striving to speak words well, loudly, and clearly is not effective if it does not conceal the genuinely internalized, purposeful, and living relationships. Soft murmuring and emphatic scolding are two sides of the same coin. Stage speech today demands deeper and more subtle methods to reveal the actor's inner life and delicate inner technique, imposing special requirements on direction. The effectiveness of speech on stage, contemporary speech, and its distinctiveness can be assessed in direct connection with truth and with the theatrical processes of the last decade. Attention to "today's" vibrant speech on stage depends on several factors, the most important being the characteristics of contemporary art, its principles, and the refinement of our ideas about its measures. Radio, cinema, television—any mass medium brings the actor closer to the audience. Modern technologies have entered theater life directly, but without exerting overwhelming influence. Sound and image are very close to the viewer; the actor's art becomes part of everyday life, of everyday reality. Norms for perceiving living speech, its height or ordinary scale, theatricality or simplicity—all underwent profound change. A wide audience, varying in education and cultural background, remained in constant

contact with the actor's art. Under this influence, the audience's artistic taste and aesthetic perception developed, as did their understanding of the "resemblance" of human behavior in real life and the actor's behavior on screen and stage (either heightened or dimmed). Another crucial factor was the ability to perceive stage reality and the effectiveness of speech. The skill of recognizing realistic behavior and hearing living speech was honed. Despite changes in perception and the proximity of daily life in theater, the criteria for live interaction on stage, as opposed to television or cinema screens, remained uncompromised. The effectiveness of stage speech in contemporary theater is influenced not only by the director's concept for a production but also by the development and transformation of the actor's art itself. The demand for natural, conversational language in today's theater is not merely legitimate—it is essential. The key question is how to understand and achieve this conversational speech. K. S. Stanislavski and V. I. Nemirovich-Danchenko considered the simplicity and naturalness of spoken language an inseparable and even defining element of theatrical art. Although Stanislavski noted, "Most people speak poorly and crudely in everyday life…," life itself served as a standard for him in measuring stage speech and verbal action. He asked, "Have you ever heard extremely simple speech on stage or in life—without extraordinary vocal effort, without rising or falling dramatically, without excessive stretching of sound intervals, without complex phonetic figures or intonational patterns? Despite the absence of all these methods to intensify expressiveness, very simple speech often produces an incomparable effect through its logic, coherence, clear grouping of words, structural organization of phrases, endurance of delivery, clarity of thought, and precision of lexical expression." Stanislavski's reflections and research in speech and voice were aimed at finding the optimal ways to cultivate stage speech as true, living, and organic speech. The central principle of such speech was, naturally, verbal action. "In life, people always speak with some goal, task, or necessity, always aiming to accomplish something through their words." On stage, verbal action arises from actively perceiving and engaging with the stylistic nature of the work, thinking and feeling, and understanding the author's text in a particular way. It is realized through the author's words, as the performer engages with the literary, stylistically refined language of the writer. This language exists as the character's speech—specific, individual, and unique verbal action within the role. Simultaneously, lexical choice, stylistic form, punctuation, and all other expressive tools are closely interconnected, conveying the vividness, emotional content, and stylistic character of the role material. Only in this structure do the typical qualities of the author's speech fully emerge. Theater, in turn, transforms the written speech of the play into living, oral expression and verbal action. It is important to note that while literary written language has been studied extensively for a long time, systematic research into verbal action began only at the end of the 1950s. In recent years, dedicated studies on verbal action have highlighted its distinctive qualities, comparing it not only with written language but also with other forms of spoken speech. Verbal action is one of the oral speech styles with its own functions and properties. Its defining features are the "specific environment of the speakers," and its content is determined by the "interests of communication at the given moment." Conversational speech is primarily dialogical, unrehearsed, and always directly dependent on the interlocutor's reception. In verbal action, intonation serves as a form of being—it plays a primary, leading role. To understand the action, task, evaluation, and relationship—in other words, the meaning—intonation is critical. Stress, pauses, and other nonverbal communication tools such as gestures and facial expressions sometimes replace detailed verbal information, allowing ambiguity, continuity, or incompleteness in speech. Researchers of verbal action have noted and identified its unique properties, distinguishing it from the intonation of other functional spoken styles. Its key characteristics—pace, intensity, pauses, and tension—vary infinitely and resist formalization or schematic patterns. Variations depend on the speaker's objectives, the communicative situation, and personal traits. Rapid, slow, relaxed, or unhurried speech occurs side by side, with careful, nearly syllabic articulation and sometimes indistinct endings or omissions of individual sounds. The spontaneity of live, direct speech produces natural pauses and silences. In concrete situations of verbal action, sentences often form continuous wholes, skipping necessary syntactic pauses and featuring non-syntactic, psychological, or physiological breaks. The main features of intonation in oral speech can be summarized as follows:

1. Intonation exhibits significant contrasts—from minimal, almost "colorless" everyday cues in meaning, clarity, and expressiveness, to highly stylized, maximally loud, and clearly expressive intonation in formal speech.

2. The precision of intonation varies, using very high and low tones, abrupt drops, and rises. Oral sentences are marked by alternation of stressed and unstressed elements, which defines both speech production and perception. Smooth alternation of rising and falling tones creates rhythm and eliminates monotony typical of codified literary language.

3. Verbal action is highly emotional ("affective speech is the best way to convey your thought to the interlocutor"). Sustained vowels are a characteristic method.

E. L. Nosenko highlights the role of the "vocal channel"—voice and breathing—in conveying emotional information. Key aspects include:

1. Pronounced deviations in fundamental frequency and intensity of speech signals.

2. Sudden changes in overall speech tone, with increased pace through articulation of speech units.

3. Increased speed of articulation (absolute speech speed).

4. Variation in the duration of the actor's or reader's reaction to cues.

5. Articulatory errors (blurred pronunciation), sometimes transforming speech into singing.

6. Increased number of words distinguished by logical stress.

7. Greater frequency of grammatically and logically incomplete phrases compared with normal speech.

Theater researchers emphasize that incomplete and indistinct articulation in verbal action can hinder comprehension of stage imagery. This ambiguity arises from quantitative and qualitative reductions in vowel sounds, shortening of vowels, loss of consonants, and loss of word beginnings, endings, or connections. All these phenomena are associated with very low intensity and slow articulation. Reduced clarity and imprecision in diction are thus natural features of living speech. Negligence in verbal action in everyday life is compensated by factors such as:

- The speed of interaction with partners
- Nonverbal means of communication
- Opportunities for repetition and correction
- Conversational habits with the interlocutor
- Lack of need for exhaustive phonetic clarity and articulation details for the purposes of dialogue

References

1. Stanislavski, K. S. Collected Works in 8 Volumes. Moscow: “Iskusstvo,” 1954–1961.

2. Zaporozhets, T. I. The Logic of Stage Language. Moscow: “Znanie,” 1974.

3. Nosenko, E. A. Speech Features in Conditions of Emotional Tension. Dnepropetrovsk: Dnepropetrovsk University Press, 1975.

4. Nemirovich-Danchenko, V. I. On the Actor’s Creativity (compiled; introductory article by V. Ya. Vilenkin). Moscow: “Iskusstvo,” 1973.

5. Nemirovich-Danchenko, V. I. During Rehearsal. Moscow: “Iskusstvo,” 1965.

6. Markov, P. A. On Theater. 4 volumes. Moscow: “Iskusstvo,” 1974–1977.

7. Contemporary Directing Art. Edited by Z. Vladimirova. Moscow: “Iskusstvo,” 1962.

8. Olga Leonardovna Knipper-Chekhov, Part 1. Moscow, 1972, pp. 53–54.

9. Cinema: Encyclopedic Dictionary. Chief editor S. I. Yutkevich; Editorial board: Yu. S. Afanasyev, V. E. Baskakov, I. V. Vaisfeld, et al. Moscow: Soviet Encyclopedia, 1987, p. 278. 640 pages, 100,000 copies.

10. Meyerhold, V. Volume 1: Biographical Materials, 1896–1903. Moscow: OGI, 1998. 744 pages.

11. Freidkina, L. M. Nemirovich-Danchenko – Teacher at the Philharmonic Theater. In: Records of the Lunacharsky State Institute of Theater Arts. Moscow: “Iskusstvo,” 1940.

12. Archives of the Moscow Art Theater named after M. Gorky, USSR.

13. Efros, N. E. Moscow Art Theater, 1898–1923. Moscow: State Publishing House, 1924.

14. Stroyeva, M. N. K. S. Stanislavski’s Directorial Research, Vol. 1. Moscow: “Nauka,” 1973.

15. Knebel, M. O. A Whole Life, 3rd edition. Moscow: NTO, 1967.

16. Tovstonogov, G. A. On the Profession of the Director, 2nd supplementary edition. Moscow: VTO, 1967.

17. Efros, A. V. Profession: Director. Moscow: “Iskusstvo,” 1979.

18. Bally, Ch. General Linguistics and the Problems of the French Language, 3rd edition. Translated from French. Moscow: “World Literature,” 1955.

BIOLOGICAL SCIENCES

THE ROLE OF LIPID METABOLISM INDICATORS, ENDOTHELIAL DYSFUNCTION PARAMETERS, AND INFLAMMATORY MARKERS IN THE PATHOGENESIS OF HYPERTENSIVE RETINOPATHY

Sharifova G.,
Mammadova F.
ORCID: 0000-0001-6382-7150
Azerbaijan Medical University, Biochemistry department
Baku, Azerbaijan
DOI: 10.5281/zenodo.19827728

ABSTRACT

The aim of this study is to conduct a comprehensive analysis of biomarkers reflecting lipid metabolism, inflammatory mediators, and the functional state of the endothelium in individuals with hypertensive retinopathy (HR) Disorders of lipid metabolism, endothelial dysfunction, and chronic inflammatory processes play a crucial pathophysiological role in the developmental mechanism of hypertensive retinopathy.

Keywords: hypertensive retinopathy, HDL, LDL, endothelin-1, interleukin-6, endothelial dysfunction, atherogenic index.

Introduction

Arterial hypertension (AH) is one of the most pressing multidisciplinary problems in modern medicine, causing severe structural and functional changes in target organs, including the retina[1;2]. Due to their high metabolic activity and specific microcirculatory structure, retinal vessels hold decisive significance ("mirror effect") in predicting systemic vascular pathologies[13]. Damage to the endothelial layer, the inner lining of the vascular wall, and the associated chronic inflammatory processes act as the central pathophysiological mechanisms in the pathogenesis of hypertensive retinopathy[11;12]. Endothelial dysfunction leads to a pathological increase in vascular permeability, the formation of exudates, and microcirculatory disturbances in the retina[9;14].

Materials and Methods

The study was conducted at the Teaching Clinical Biochemistry Laboratory of the Azerbaijan Medical University. The study included a group of 42 patients with retinopathy developed against the background of arterial hypertension and a control group of 18 practically healthy individuals. Lipid profile parameters (total cholesterol, LDL-C, HDL-C, triglycerides) were determined using the "Mindray BA-88A" biochemical analyzer. The level of endothelin-1 (ET-1), a marker of endothelial damage, was measured via enzyme-linked immunosorbent assay (ELISA) using "Elabscience" (China) reagent kits on a "Mindray MR-96A" device. The inflammatory parameter, interleukin-6, was determined using the electrochemiluminescence (ECLIA) method. The obtained numerical data were processed using variational statistics methods, and results were presented as mean values and standard deviation. Pearson's correlation coefficient and the Mann-Whitney U test were utilized to evaluate the degree of dependence between the indicators.

Results

The conducted research and statistical analyses allow for the following conclusions:

In patients with hypertensive retinopathy, the primary indicators of lipid metabolism were found to be at elevated levels: total cholesterol averaged 5.87 ± 0.17 mmol/L, triglycerides (TG) 4.13 ± 0.13 mmol/L, and LDL 4.36 ± 0.16 mmol/L.

Table 1.

Comparative characteristics of lipid profiles in patients and the control group

Groups / Indicators	Control group (n=18)	Patient group (n=42)	P (Mann–Whitney test) (U)
Total cholesterol,mmol/l	3,64±0,15	5,87±0,17	P<0,001
Triglycerides,mmol/l	1,22±0,04	4,13±0,13	P<0,001
HDL cholesterol,mmol/l	1,51±0,04	0,72±0,04	P<0,001
LDL cholesterol,mmol/l	2,06±0,09	4,36±0,16	P<0,001

The average level of high-density lipoproteins (HDL) was found to be 0.72 ± 0.04 mmol/L, indicating a significant reduction in this protective factor. Table 1

Endothelin-1, a critical marker of the functional state of the endothelium, reached a mean level of 10.35 ± 0.35 pg/mL (max: 13.45 pg/mL), signaling profound alterations within the vascular endothelium.

Interleukin-6, a parameter reflecting the involvement of inflammatory responses in the progression of the disease, averaged 5.86 ± 0.67 pg/mL, with values rising as high as 14.51 pg/mL in certain patients.

Table 2.

Levels of vascular endothelial and inflammatory markers in the studied groups

1	Control group (n=18)	Patient group (n=42)	P (Mann–Whitney test) (U)
Endothelin-1, pg/ml	2,81±0,17	10,35±0,35	P<0,001
Interleukin-6, pg/ml	1,39±0,17	5,86±0,67	P<0,001

Discussion

The results of this study indicate that lipid metabolism disorders, endothelial dysfunction, and inflammatory processes play a pivotal role in the developmental mechanism of hypertensive retinopathy (HR). Significant alterations were observed in the levels of total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C), which are critical in the development of atherosclerosis; these changes increase the risk of atherogenic modifications in the vascular walls [5;7;10]. Furthermore, the determination of interleukin-6, an inflammatory mediator, highlights the presence of a chronic inflammatory component in the pathogenesis of the disease [6;8;11]. Comparative analysis with the control group confirms that these biochemical markers serve as objective criteria for the diagnosis and prognosis of hypertensive retinopathy.

The alteration of the lipid spectrum in the context of HR confirms the occurrence of profound atherogenic transformations within the organism [7;10]. The disorders observed in the lipid profile of the study group are among the primary causes of lipid peroxidation and structural damage to the vascular walls within the microcirculatory bed [3;4;5]. The fact that the average level of HDL, which possesses anti-atherogenic properties, remained below the norm (0.72 ± 0.04 mmol/L) proves that the degree of dyslipidemia is a significant risk factor in the progression of the disease [3].

In assessing the functional state of retinal vessels, the level of endothelin-1, which exerts a potent vasoconstrictive effect, serves as a crucial prognostic criterion. The elevation of this indicator in patients signifies a loss of the endothelium's ability to regulate the balance between vasodilation and vasoconstriction [9]. This dysfunction directly impacts the disruption of retinal blood supply and the deepening of ischemic changes during hypertensive retinopathy [12].

Conclusion

The results of this comprehensive study prove that hypertensive retinopathy is not merely an isolated hemodynamic disorder but a complex pathological process accompanied by the active involvement of systemic chronic inflammation. The statistically significant increase in the levels of the pro-inflammatory cytokine Interleukin-6 (IL-6) in the study group is evaluated as a direct indicator of neurohumoral dysregulation and immunological destruction occurring within the retinal microcirculatory bed. This phenomenon fundamentally confirms that low-grade systemic inflammation plays a decisive role in the pathogenesis of retinal damage.

Multidisciplinary analyses conducted on the group of 42 patients revealed a significant correlation between lipid metabolism disorders, endothelial dysfunction, and the activity of inflammatory mediators. This reciprocal mechanism demonstrates that the pathogenesis of HR is built upon a "pathological triad" consisting of the integration of lipid peroxidation, endothelial dysfunction, and the cytokine cascade.

In conclusion, the determination of pro-inflammatory indicators alongside markers of endothelial dysfunction holds substantial diagnostic importance in predicting the disease and objectively assessing the degree of complications. The obtained results scientifically justify the necessity of incorporating not only hypotensive therapy but also endothelioprotective and targeted anti-inflammatory approaches into the treatment strategies for hypertensive retinopathy.

References

1. NCD Risk Factor Collaboration (NCD-RisC). (2021). Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019. The Lancet, 398(10304), 957-980.

2. Wong, T. Y., & Mitchell, P. (2014). The eye in hypertension. The Lancet, 364(9432), 410-422.

3. Mammadova F.I. Chronic heart failure and apoptosis markers in patients with metabolic syndrome. Azerbaijan Medical Journal. 2019;(4):90–94.

4. Mamedova F.I. Vliyanie oksidativnogo stressa na sostoyanie endotelia u patsientov s serdechnoy nedostatochnost'yu I sakharным diabetom 2-go tipa. Kazansky Meditsinsky Zhurnal. 2020;101(1):13–17.

5. Goulopoulou, S., & Webb, R. C. (2014). Orchestrating vascular health: vascular muscle cell–endothelial cell communication. Circulation, 130(9), 742-744.

6. Ridker, P. M. (2016). From C-Reactive Protein to Interleukin-6 to Interleukin-1: Moving Upstream to Identify Novel Targets for Atheroprotection. Journal of the American College of Cardiology (JACC), 67(20), 2419-2423.

7. Tall, A. R., & Yvan-Charvet, L. (2015). Cholesterol, inflammation and innate immunity. Progress in Lipid Research, 15(1), 121-134.

8. Tanaka, T., Narazaki, M., & Kishimoto, T. (2014). IL-6 in inflammation, immunity, and disease. Cold Spring Harbor Perspectives in Biology, 6(10), a016295.

9. Wong, T. Y., & Mitchell, P. (2014). The eye in hypertension. The Lancet, 364(9432), 410-422

10. Vatavuk, Z., & Iveković, R. (2020). Lipid profile and hypertensive retinopathy: Is there a link? Ophthalmologia Croatica, 28(1), 12-18.

11. Badami, K. G., & Kumar, P. (2021). Interleukin-6 and its correlation with severity of retinal vascular diseases. Journal of Ocular Inflammation and Infection, 11(1), 5-12.

12. Ergul, A. (2011). Endothelin-1 and diabetic retinopathy: focus on the disease progression. Journal of Cardiovascular Pharmacology, 57(2), 140-144.

13. Flammer, J., & Konieczka, K. (2017). Retinal vascular involvement in systemic hypertension. Current Hypertension Reports, 19(8), 63.

14. Modjtahedi, B. S., & Abbott, R. L. (2011). Ocular manifestations of systemic hypertension. Current Opinion in Ophthalmology, 22(6), 484-490.

CHEMICAL SCIENCES

SYNTHESIS AND ANTIMICROBIAL ACTIVITY OF SOME ADAMANTYL-CONTAINING HYDRAZONES

Koshchii I.
PhD in Chemistry, Associate Professor
Department of Organic Chemistry and Technology of Organic Substances
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Klimko Yu.
PhD in Chemistry, Senior Lecturer
Department of Organic Chemistry and Technology of Organic Substances
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
DOI: 10.5281/zenodo.19827743

ABSTRACT

Several adamantyl-containing quaternary salts of benzylidenehydrazinylpyridine, based on benzyl, ethylphenyl, and propylphenyl groups on the pyridinium nitrogen, were synthesized and tested for potential antibacterial and antifungal activity against Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Candida albicans using a microdilution method. Results of antimicrobial testing showed that compounds containing the 3-phenylpropyl chain exhibited the highest antimicrobial activity against Staphylococcus aureus, and compound 3d was the most active in the series against all bacterial and fungal strains tested.

Keywords: hydrazones, pyridinium salts, adamantyl, antimicrobial activity.

Introduction

The shortage of new antibacterial drugs due to growing bacterial resistance to antimicrobial agents is a major challenge in the development of new drugs. Quaternary amine derivatives have previously been reported to exhibit antimicrobial properties [1–4]. Certain mono- and bis-quaternary ammonium compounds, including various alkyl chain lengths with various hydrophobic substituents, have been found to exhibit antimicrobial activity [5–7].

Pyridinium halides, like quaternary nitrogen salts, exhibit antimicrobial properties and adsorption properties on negatively charged solids. The antimicrobial activity of 1-alkylpyridinium salts depends on their adsorption activity on the surface of bacterial cells [8–16] and the pKa values of the corresponding pyridines [17]. The factors that control their antimicrobial activity are molecular hydrophobicity [18,19], adsorbability [20], surface activity [19] and electron density [21,22] of the quaternary nitrogen atom.

These compounds have one hydrophobic alkyl chain and one hydrophilic quaternary nitrogen ion group in one molecule, which provides greater surface activity and more pronounced antimicrobial activity compared to conventional antimicrobial agents [23].

On the other hand, Schiff bases are important in medicine, and their biological activities have been reported in many studies [24,25]. Hydrazones, a special group of Schiff bases, are also known as one of the most important classes of organic compounds, some of which exhibit significant biological activities such as antimicrobial [26–30], antituberculosis [31–33], anticancer [34–36], analgesic [37], anti-inflammatory [37], antiplatelet [38], and antiviral [39, 40] activities. The data reported in these studies showed that the side chain attached to the pyridinium nitrogen significantly affected the antimicrobial activity. Among them, compounds with 3-phenylpropyl chains showed remarkable activity [40].

Based on these results, ortho-methyl, -methoxyl, -hydroxyl benzylidenehydrazinylpyridinium salts with benzyl, 2,6-dichlorobenzyl, 2-phenylethyl, and 3-phenylpropyl groups on the pyridine nitrogen were prepared to study the effect of such structural modifications of quaternary pyridinium salts on the expected antimicrobial activity.

In addition to the above, the objective of this study was to introduce a bulky hydrocarbon radical, adamantane, into the Schiff base molecules. The latter is widely known to enhance the lipophilicity of the drug substance, which prolongs its therapeutic effect.

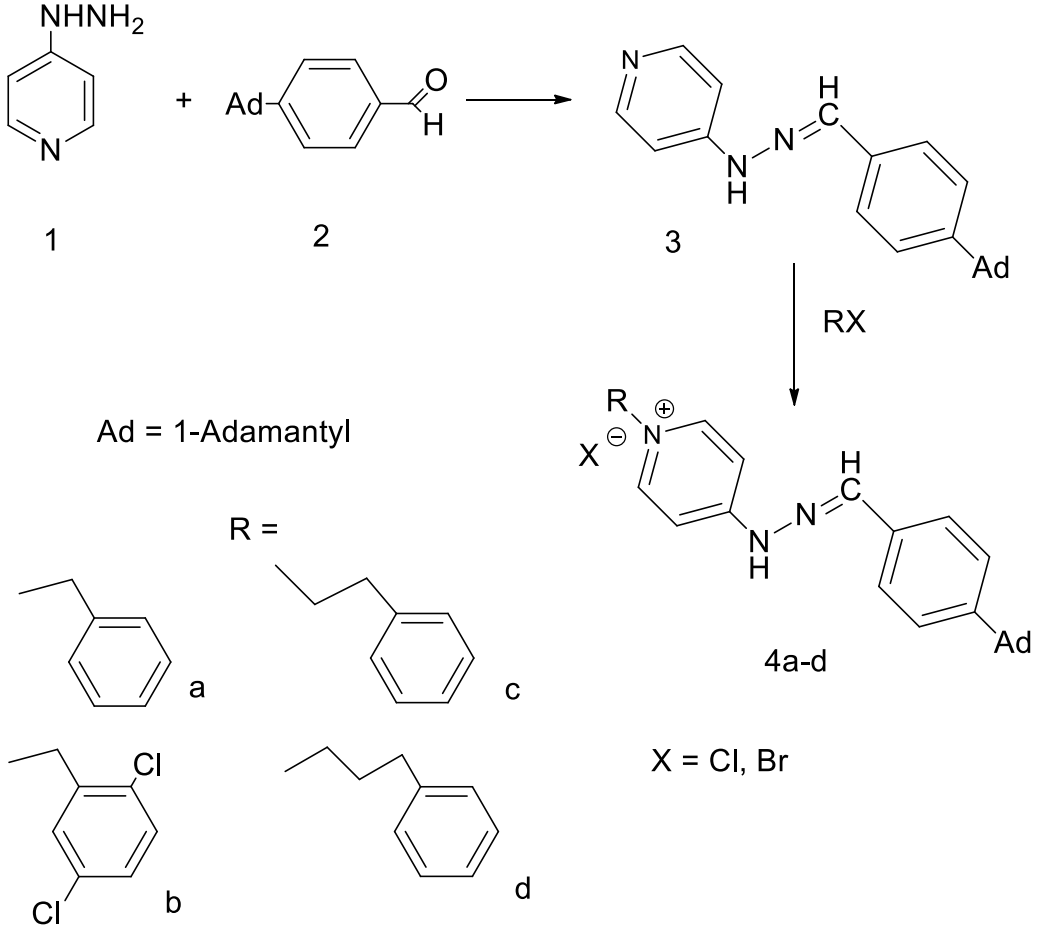
Results and Discussion

Chemistry

Benzylidenehydrazinylpyridinium salts were prepared in three steps according to the reported procedure [41] as shown in Scheme 1. In the first step, 4-chloropyridine was refluxed with hydrazine hydrate in 1-propanol to give 4-hydrazinylpyridine (1). This compound was then condensed with 4-(1-adamantyl)benzaldehyde (2) in ethanol at room temperature to give hydrazone (3). In the last step, the final compounds (4a–d) were obtained by quaternization of hydrazone derivatives (3) with the appropriate substituted alkyl halides in ethanol under reflux. All the key compounds are new. Except for compounds (3) and (4), compounds (1) and (2) were previously described [42,43].

The structures of the final compounds were determined by spectral methods. The IR spectra of the final compounds showed intense absorption bands in the range of 3315–3446 cm−1 and the range of 1436–1644 cm−1, which were assigned to vibrations of the NH and C=N functions, respectively. In the 1H NMR spectra, the signals of the NH group protons were recorded in the range of 12.26–13.00 ppm. The signals of the protons belonging to the N=CH group were observed as singlets in the range of 8.52–8.65 ppm. The IR and 1H NMR data confirmed the condensation between the

amino and carbonyl groups. As expected, while the pyridine hydrogens at positions 2 and 6 of compound (3) showed peaks in the 8.19–8.21 ppm range, the signals of the hydrogens at these positions were in the final compounds (4a–d) in the 8.30–8.55 ppm range [44]. The shifts of these peaks to higher frequency indicated that compounds (4) were quaternized with an alkyl halide. All 13C NMR results supported the proposed structures as stated in the experimental section. The mass spectra of the final compounds (4a–d) showed molecular ion peaks that were consistent with the proposed structures.



Scheme 1. Synthesis of the title compounds

Antimicrobial Activity

A series of benzylidenehydrazinylpyridinium salts with an adamantyl substituent at the para-position of the benzene ring were evaluated for antimicrobial activity against Gram-positive and Gram-negative bacteria and fungi. The bacterial strains represented important Gram-positive and Gram-negative species, including Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa. Their antibacterial activity was assessed by measuring the minimum inhibitory concentration (MIC) using a standard broth dilution assay (Table 1).

Based on the antimicrobial activity results, all compounds exhibited high antimicrobial activity against Staphylococcus aureus and low antimicrobial activity against Pseudomonas aeruginosa. Among the tested compounds, 4d was the most active derivative against Staphylococcus aureus, being as effective against this microorganism as the standard compound ceftazidime. The results showed that the longer the side chain of a compound, the greater its antimicrobial activity. In the series of adamantyl-substituted phenylpropyl derivatives, the antimicrobial activity of 4d was followed by 4c, 4a, and 4b, respectively. No significant difference in the antibacterial activity of compounds 4c and 4a was observed. Both compounds had identical MIC values against the test microorganisms, with the exception of Pseudomonas aeruginosa. According to the MIC values of the compounds, 4d had the lowest MIC values (4 μg/mL) compared to other pyridinium salts.

Table 1.

Antimicrobial activity of compounds **4a-d**.

Compound No	*Minimum Inhibitory Concentration (MIC) (μg/mL)*			
	E. coli	*P. aeruginosa*	*S. aureus*	*C. albicans*
4a	*35*	*512*	*20*	*66*
4b	*>2048*	*>2048*	*67*	*1030*
4c	*66*	*512*	*32*	*66*
4d	*131*	*1030*	*4*	*66*
Ceftazidime	***<0.125 (0.06-0.5)****	*1 (1–4)**	*4 (4–16)**	
Fluconazole		–	–	*(0.25–1.0)**

* Acceptable quality control ranges of minimum inhibitory concentrations (MICs) (μg/mL) for strains [45,46].

This bioisosteric substitution resulted in a slight increase in antimicrobial activity. On the other hand, compounds with a 2,6-dichlorobenzyl side chain on the pyridinium nitrogen showed no activity against Gram-negative bacteria. Our study showed that all compounds exhibited stronger antibacterial activity against Gram-positive bacteria compared to Gram-negative bacteria.

These data suggest that pyridinium salts act on cell membranes, and the surface activity of these compounds may be primarily responsible for their antibacterial properties. However, all tested compounds exhibited low antifungal activity against *Candida albicans*. The weaker antifungal activity compared to the antibacterial effect may be due to differences in the compounds' mechanisms of action in inhibiting the fungal cell respiration system, rather than cell wall destruction.

Materials and methods

The melting points (mp) of the synthesized compounds were recorded on a Boetius bench. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AM300 spectrometer (300 and 75 MHz, respectively) in DMSO-d6 and $CDCl_3$ at 25 °C. Chemical shifts were measured in DMSO-d6 with TMS as an internal standard. IR spectra were recorded using the thin film method and in KBr tablets on a Bruker Alpha spectrometer. Electrospray ionization (ESI) mass spectra were measured on an Agilent 1100 LC/MSD instrument. Reagents and solvents used for the synthesis were purchased from Aldrich. 4-(1-Adamantyl)benzaldehyde was provided by Akos GmbH. Thin-layer chromatography was performed on silica gel-coated 60 F254 plates (Merck). The spots were developed using UV light or iodine.

Synthesis of 4-Hydrazinopyridine Hydrochloride (1).

Compound (1) was prepared according to the method described in [47]. A solution of 4-chloropyridine (0.01 mol) and hydrazine monohydrate (0.15 mol) in 1-propanol (30 ml) was refluxed for 18 h. The solution was cooled to 0 °C, the precipitate was filtered off, washed with cold 1-propanol, and crystallized from ethanol. M.p. 242–243 °C (ref. [47,48], 242–243 °C).

4-(2-(4-(1-Adamantyl)benzylidene)hydrazinyl)pyridine (3).

4-Hydrazinylpyridine (0.01 mol) and benzaldehyde derivative (2) (0.01 mol) were stirred in ethanol (30 ml) at room temperature for 4–9 h. The precipitate was filtered off, washed with cold ethanol, and crystallized from ethanol. Yield 73%. M.p. 232 °C. IR (ν, cm^{-1}): 1427, 1452, 1486, 1527, 1538 (Ar-C=C and N=C), 2886, 2948 (aliphatic C-H), 3014 (Ar-C-H), 3210 (N-H); ^{1}H NMR (δ, ppm): 1.76 ($6CH_2$, Ad), 1.87 (3CH, Ad), 6.97 (2H, d, J = 6.2 Hz, Py-H), 7.23 (2H, d, J = 8.2 Hz, Ar-H), 7.83 (2H, d, J = 8.2 Hz, Ar-H), 8.19 (1H, s, N=CH), 8.21 (2H, d, J = 6.2 Hz, Py-H), 10.80 (1H, s, NH).

General procedure for the synthesis of compounds (4a-d).

Hydrazone (3) (0.01 mol) and the corresponding alkyl halide (0.02 mol) were refluxed in ethanol (30 mL) for 10-40 h. The mixture was cooled to 0 °C, and the resulting precipitate was filtered and washed with cold ethanol. The crude products were crystallized from ethanol, yielding compounds (4a-d).

1-Benzyl-4-(2-(4-(1-adamantyl)benzylidene)hydrazinyl)pyridine chloride (4a). Yield 68%. M.p. 267 °C. IR (ν, cm^{-1}): 1455, 1482, 1517, 1544, 1600, (Ar-C=C and N=C), 1644 (N^{+}=C), 2838, 2911, 2979 (aliphatic C-H), 3037 (Ar- C-H), 3397 (N-H). ^{1}H-NMR (δ, ppm): 1.76 ($6CH_2$, Ad), 1.87 (3CH, Ad), 5.48 (2H, s, N^{+}-CH_2-Ph), 7.16 (1H, dd, J = 7.0, 2.3 Hz, Py-H), 7.23 (2H, d, J = 8.2 Hz, Ar-H), 7.83 (2H, d, J = 8.2 Hz, Ar-H), 7.36-7.42 (5H, m, Ar-H), 7.56 (1H, d, J = 7.4 Hz, Py-H), 8.47 (1H, d, J = 7.4 Hz, Py-H), 8.55 (1H, d, J = 7.4 Hz, Py-H), 8.62 (1H, s, N=CH), 13.00 (1H, s, NH). ^{13}C NMR (δ, ppm): 60.75 107.80, 109.64, 126.96, 127.47, 128.78, 129.46, 129.78, 130.9, 131.7, 132.18, 136.20, 137.92, 143.72, 144.89, 147.99, 154.38. MS (*m/z*): 458 ($M^{+\bullet}$), 91.135, 77.

1-(2,6-Dichlorobenzyl)-4-(4-(1-adamantyl)benzylidene)hydrazinyl)pyridinium chloride (4b).

Yield 72%. M.p. 298 °C; IR (ν, cm^{-1}): 1436, 1513, 1581 (Ar-C=C and N=C), 1644 (N^{+}=C), 2694, 2886 (aliphatic C-H), 3052 (Ar-C-H), 3442 (N-H). 1H NMR (δ, ppm): 1.76 ($6CH_2$, Ad), 1.87 (3CH, Ad), 5.70 (2H, s, N^{+}-CH_2-Ph), 7.14 (1H, dd, J = 7.2, 2.8 Hz, Py-H), 7.26-7.30 (2H, m, Ar-H), 7.34 (1H, td, J = 7.4, 1.2 Hz, Ar-H), 7.52-7.56 (2H, m, Py -H), 7.23 (2H, d, J = 8.2 Hz, Ar-H), 7.83 (2H, d, J = 8.2 Hz, Ar-H), 8.22 (1H, dd, J = 7.0, 1.6 Hz, Py-H), 8.34 (1H, dd, J = 7.2, 1.6 Hz, Py-H), 8.60 (1H, s, N=CH), 13.00 (1H, s, NH). ^{13}C-NMR (δ, ppm): 56.44, 108.29, 110.28, 125.29, 128.30, 129.22, 129.72, 130.00, 131.74, 133.16, 134.16, 137.00, 143.50, 144.66, 144.74, 148.69, 154.80. MS (m/z): 527 ($M^{+\bullet}$), 135, 159, 145.

4-(4-(1-Adamantyl)benzylidene)hydrazinyl)-1-phenethylpyridinium bromide (4c). Yield 87%. M.p.190 °C. IR (ν, cm^{-1}): 1455, 1513, 1546, 1577 (Ar-C=C and N=C), 1644 (N^+=C), 2836, 2908 (aliphatic C-H), 3054 (Ar-C-H), 3415 (N-H); ^{1}H NMR (δ, ppm): 1.76 (6CH_2, Ad), 1.87 (3CH, Ad), 3.13 (2H, t, J = 7.2 Hz, N^+-CH_2-CH_2-Ph), 4.50 (2H, t, J = 7.2 Hz, N+-CH_2-CH_2-Ph), 7.03 (1H, dd, J = 7.0, 2.3 Hz, Py-H), 7.19-7.36 (5H, m, Ar-H), 7.23 (2H, d, J = 8.2 Hz, Ar-H), 7.83 (2H, d, J = 8.2 Hz, Ar-H), 7.50 (1H, dd, J = 7.0, 2.3 Hz, Py-H), 8.30 (1H, d, J = 7.4 Hz, Py-H), 8.35 (1H, d, J = 7.0 Hz, Py-H), 8.53 (1H, s, N=CH), 12.38 (1H, s, NH). ^{13}C NMR (δ, ppm): 36.92, 59.03, 107.37, 108.99, 126.94, 127.36, 127.55, 129.23, 129.62, 130.96, 131.73, 132.12, 137.33, 137.89, 143.71, 144.84, 147.53, 154.10. MS (*m/z*): 513($M^{+\bullet}$), 77, 91, 135.

*4-(4-(1-Adavantyl)benzylidene)hydrazinyl)-1-(3-phenylpropyl)pyridinium bromide (4d).*Yield 49%. M.p.160 °C; IR (ν, cm^{-1}): 1454, 1488, 1511, 1552, 1585, (Ar-C=C and N=C), 1644 (N^+=C), 2827, 2915 (aliphatic C-H), 3058 (Ar-C-H), 3424 (N-H); ^{1}H NMR (δ, ppm): 1.76 (6CH_2, Ad), 1.87 (3CH, Ad), 2.12 (2H, quin, J = 7.6 Hz, N+-CH_2-CH_2-CH_2-Ph), 2.60 (2H, t, J = 7.8 Hz, N^+-CH_2-CH_2-CH_2-Ph), 4.28 (2H, t, J = 7.2 Hz, N^+-CH_2-CH_2-CH_2-Ph), 7.06 (1H, dd, J = 7.2, 2.4 Hz, Py-H), 7.16-7.30 (5H, m, Ar-H), 77.56 (1H, dd, J = 6.8, 2.4 Hz, Py-H), 7.23 (2H, d, J = 8.2 Hz, Ar-H), 7.83 (2H, d, J = 8.2 Hz, Ar-H) 8.39 (1H, d, J = 6.8 Hz, Py-H), 8.46 (1H, d, J = 7.2 Hz, Py-H), 8.52 (1H, s, N=CH), 12.34 (1H, s, NH); ^{13}C NMR (δ, ppm): 32.28, 52.50, 58.08, 107.50, 109.15, 126.76, 126.98, 127.50, 128.89, 129.12, 131.00, 131.80, 132.14, 137.33, 141.15, 143.79, 144.80, 147.64, 154.29. MS(*m/z*): 527 ($M^{+\bullet}$), 77, 91, 135.

Antimicrobial activity

Minimum inhibitory concentration (MIC) was determined by broth microdilution according to the Clinical and Laboratory Standards Institute (CLSI) [45,46]. The in vitro antimicrobial activity of the final compounds (4a-d) was assessed against standard strains: Staphylococcus aureus ATCC 29213, Escherichia coli ATCC 25922, Pseudomonas aeruginosa ATCC 27853, and Candida albicans ATCC 90028. Antibacterial and antifungal assays were performed in Mueller-Hinton broth and Sabouraud dextrose broth, respectively. All synthesized compounds were weighed (10 mg), dissolved in DMSO (250 µL), and diluted with water (750 µL) to prepare stock solutions of 10 mg/mL. Serial dilutions from 2048 to 1 µg/mL were performed in a 96-well plate. Fifty µL of bacterial suspension obtained from a 24-hour culture (~106 CFU/mL) was added to each well with a final DMSO concentration of 1:16. The plates were incubated at 35°C for 24 hours. We tested Ceftazidime as an antimicrobial agent for quality control of the method. Each experiment was repeated twice.

Conclusions

In conclusion, we described the synthesis of a series of adamantyl-containing benzylidenehydrazinylpyridinium salts (4a-d) with antimicrobial activity. The final synthesized compounds were characterized by spectral data (IR, 1H-NMR, 13C-NMR, MS). Both the synthesis and antimicrobial activity of the final compounds (4a-d) were reported for the first time. Compounds (4a-d) were found to possess moderate activity against S. aureus. Notable activity was observed for compounds bearing a 3-phenylpropyl side chain on the nitrogen atom. The most active compound was 4-(4-(1-adamantylbenzylidene)hydrazinyl)-1-(3-phenylpropyl)pyridinium bromide (4d), with an MIC of 4 µg/mL against S. aureus. Results showed that a longer side chain on the pyridinium nitrogen resulted in increased activity.

References

1. Thorsteinsson, T.; Masson, M.; Kristinsson, K.G.; Hjalmarsdottir, M.A.; Hilmarsson, H.; Loftsson, T. Soft antimicrobial agents: Synthesis and activity of labile environmentally. Friendly long chain quaternary ammonium compounds. *J. Med. Chem.* 2003, *46*, 4173–4181.

2. Vnutskikh, Z.A.; Shklyaev, Y.V.; Odegova, T.F.; Chekryshkin, Y.S.; Tolstikov, A.G.; El'chishcheva, N.V.; Syropyatov, B.Y. Synthesis and antimicrobial activity of mono-and biquaternized derivates of dipyridylethanes and dipyridylethylenes. *Khim. Farm. Zh.* 2006 *40*,19–22.

3.Ovchinnikova, I.G. Fedorova, O.V.; Rusinov, G.L.; Zueva, M.N.; Mordovskoi, G.G.S ynthesis and antimicrobial activity of N-alkylpyridinium podands. *Khim. Farm. Zh.*2003, *37*, 17–19.

4. Burke, J.R. and Frey, P.A. Correlation of electronic effects in *N*-alkylnicotinamides with NMR chemical shifts and hydride transfer reactivity. *J. Org. Chem.* 1996, *61*, 530–533.

5. Clarissa, K.L.N.; Singhal, V.; Widmer, F.; Wright, L.C.; Sorrell, T.C.; Jolliffe, K.A. Synthesis, antifungal and haemolytic activity of a series of bis(pyridinium)alkanes. *Bioorg. Med. Chem*.2007, *15*, 3422–3429.

6. Zhao, T.; Sun, G. Hydrophobicity and antimicrobial activities of quaternary pyridinium salts. *J.Appl. Microbiol*. 2008, *104*, 824–830.

7. Kourai, H.; Yabuhara, T.; Shirai, A., Maeda, T.; Nagamune, H. Synthesis and antimicrobial activities of a series of new bis-quaternary ammonium compounds. *Eur. J. Med. Chem.* 2006, *41*,437–444.

8. Okazaki, K.; Maeda, T.; Nagamune, H.; Manabe, Y.; Kourai, H. Synthesis and antimicrobial characteristics of 4,4'(α,ωpolymethylenedithio)bis(1alkylpyridinium iodide)s. *Chem. Pharm. Bull.* 1997, *45*, 1970–1974.

9. Maeda, T.; Okazaki, K.; Nagamune, H.; Manabe, Y.; Kourai, H. Bactericidal action of 4,4'-(α,ω-polymethylenedithio)bis-(1-alkylpyridinium iodide)s. *Biol. Pharm. Bull*. 1998, *21*, 1057–1061.

10. Maeda, T.; Manabe, Y.; Yamamoto, M.; Yoshida, M.; Okazaki, K.; Nagamune, H.; Hiroki, K. Synthesis and antimicrobial characteristics of novel biocides. 4,4'-(1,6-Hexamethylene dioxydicarbonyl)bis(1-alkylpyridinium iodide)s. *Chem. Pharm. Bull.* 1999, *47*, 1020–1023.

11. Yoshida, M.; Maeda, T.; Okazaki, K.; Nagamune, H.; Kunikata, K.; Tsuchiya, H.; Tetsuto, N.; Hiroki, K. Synthesis and antimicrobial characteristics of

N,N'-Hexamethylenebis(4-carbamoyl-1- decylpyridinium bromide). *Biocontrol Sci.* 2000, *5*, 65–71.

12. Yoshida, M.; Maeda, T.; Okazaki, K.; Nagamune, H.; Kunikata, K.; Tsuchiya, H.; Namba, T.; Kourai, H. Synthesis of 4,4'-(tetramethylenedicarbonyldiamino)-bis(1-decylpyridinium bromide) and its antimicrobial and deodorant characteristics. *Biocontrol Sci.* 2001, *6*, 75–80.

13. Shirai, A.; Maeda, T.; Hara, I.; Yoshinari, A.; Nagamune, H.; Kourai, H. Antimicrobial characteristics of bis-quaternary ammonium compounds possessing a *p*-phenylene group in their spacer chains. *Biocontrol Sci.* 2003, *8*, 151–157.

14. Pernak, J.; Rogoz, J.; Mirska, I. Synthesis and antimicrobial activities of new pyridinium and benzimidazolium chlorides. *Eur. J. Med. Chem*. 2001, *36*, 313-320.

15. Viscardi, G.; Quagliotto, P.; Barolo, C.; Savarino, P.; Barni, E.; Fisicaro, E. Synthesis and surface and antimicrobial properties of novel cationic surfactants. *J. Org. Chem.* 2000, *65*, 8197–8203.

16. Kourai, H.; Takechi, H.; Horie, T.; Uchiwa, N.; Takeichi, K.; Shibasaki, I. The antimicrobial characteristics of quaternary ammonium salts. Part X. Antimicrobial characteristics and a mode of action of *N*-alkylpyridinium iodides against *Escherichia coli. J. Antibact. Antifung. Agents* 1985, *13*, 3–10.

17. Kourai, H.; Takechi, H.; Horie, T.; Takeichi, K.; Shibasaki, I. The antimicrobial characteristics of quaternary ammonium salts. Part XI. Quantitative structure-activity relationship of antimicrobial N-laurylpyridinium iodides. *J. Antibact., Antifung. Agents* 1985, *13*, 245–253.

18. Kourai, H.; Machikawa, F.; Horie, T.; Takeichi, K.; Shibasaki, I. The antimicrobial characteristics of quaternary ammonium salts. Part IX. Quantitative structure-activity correlation on antimicrobial activity and hydrophobicity of N-alkylypyridinium iodide derivatives. *J. Antibact.Antifung. Agents* 1983, *11*, 553–562.

19. Kourai, H.; Manabe, Y.; Matsutani, E.; Hasegawa, Y.; Nakagawa, K. Antimicrobial activities of alkylallyldimethylammonium iodides andalkylallyldiethylammonium iodides. *J. Antibact. Antifung. Agents*. 1995, *23*, 271–280.

20. Kourai, H.; Machikawa, F.; Horie, T.; Takeichi, K.; Shibasaki, I. The antimicrobial characteristics of quaternary ammonium salts. Part VII. Quantitative relation between antimicrobial activity and adsorbability of N-octylquinolinium iodide on Escherichia Coli K12. *J. Antibact. Antifung. Agents* 1983, *11*, 51–54.

21. Maeda, T.; Goto, S.; Manabe, Y.; Okazaki, K.; Nagamune, H.; Kourai, H. Bactericidal action of N-alkylcyanopyridinium bromides against Escherichia Coli K12 W3110. *Biocontrol Sci.* 1996, *1*, 41–49.

22. Okazaki, K.; Maeda, T.; Nagamune, H.; Kourai, H. Quantitative structure-activity relationship ofantibacterial dodecylpyridinium iodide derivatives. *Biocontrol Sci.*1996, *1*, 51–59.

23. Shirai, A.; Maeda, T.; Nagamune, H.; Matsuki, H.; Kaneshina, S.; Kourai, H. Biological and physicochemical properties of gemini quaternary ammonium compounds in which the positions of a cross-linking sulfur in the spacer differ. *Eur. J. Med. Chem.* 2005, *40*, 113–123.

24. Sridhara, S.K.; Pandeyab, S.N.; Stablesc, J.P.; Ramesha, A. Anticonvulsant activity of hydrazones, Schiff and Mannich bases of isatin derivatives. *Eur. J. Pharm. Sci.* 2002, *16*,129–132.

25. Pandeya, S.N.; Sriram, D.; Nath, G.; De Clercq, E. Synthesis and antimicrobial and Mannich bases of isatin and its derivatives with pyrimidine. *Farmaco* 1999, *54*, 624–628.

26. Vicini, P.; Zani, F.; Cozzini, P.; Doytchinova, I. Hydrazones of 1,2benzisothiazole hydrazides: synthesis, antimicrobial activity and QSAR investigations. *Eur. J. Med. Chem*. 2002, *37*,553–564.

27. Gössnitzera, E.; Feierlb, G.; Wagnerb, U. Synthesis, structure investigations, and antimicrobial activity of selected s-*trans*-6-aryl-4-isopropyl-2-h2-[I-1-phenylalkylidene]-I-hydrazino 1,4-dihydropyrimidine hydrochlorides. *Eur. J. Pharm. Sci.* 2002, *15*, 49–61.

28. Küçükgüzel, Ş.G.; Mazi, A.; Şahin, F.; Öztürk, S.; Stables, J.P. Synthesis and biological activities of diflunisal hydrazide-hydrazones. *Eur. J. Med. Chem*. 2003, *38*, 1005–1009.

29. Loncle, C.; Brunel, J.; Vidal, N.; Dherbomez, M.; Letourneux, Y. Synthesis and antifungal activity of cholesterol-hydrazone derivatives. *Eur. J. Med. Chem*. 2004, *39*, 1067–1071.

30. Masunari, A.; Tavares, L.C. A new class of nifuroxazide analogues: Synthesis of 5-nitrophene derivatives with antimicrobial activity against multidrug-resistant *Staphylococcus aureus. Bioorg.Med. Chem*. 2007, *15*, 4229–4236.

31. Savini, L.; Chiasserini, L.; Gaeta, A.; Pellerano, C. Synthesis and anti-tubercular evaluation of quinolylhydrazones. *Bioorg. Med. Chem*. 2002, *10*, 2193–2198.

32. Kaymakçıoğlu, B.K.; Rollas, S. Synthesis, characterization and evaluation of antituberculosis activity of some hydrazones. *Il Farmaco.* 2002, *57*, 595–599

33. Gemma, S.; Savini, L.; Altarelli, M.; Tripaldi, P.; Chiasserini, L.; Coccone, S.S.; Kumar, V.; Camodeca, C.; Campiani, G.; Novellino, E.; Clarizio, S.; Delogu, G.; Butini, S. Development of antitubercular compounds based on a 4-quinolylhydrazone scaffold. Further structure–activity relationship studies. *Bioorg. Med. Chem.* 2009, *17*, 6063–6072.

34. Pandey, J.; Pal, R.; Dwivedi, A.; Hajela, K. Synthesis of some new diaryl and triaryl hydrazone derivatives as possible estrogen receptor modulators. *Arzneimittelforschung* 2002, *52*, 39–44.

35. Savini, L.; Chiasserini, L.; Travagli, V.; Pellerano, C.; Novellino, E.; Cosentino, S.; Pisano, M.B. New α-heterocyclichydrazones: evaluation of anticancer, anti-HIV and antimicrobial activity. *Eur. J. Med. Chem*. 2004, *39*, 113–122.

36. Cocco, M.T.; Congiu, C.; Lilliu, V.; Onnis, V. Synthesis and *in vitro* antitumoral activity of new hydrazinopyrimidine-5-carbonitrile derivatives. *Bioorg. Med. Chem*. 2005, *14*, 366–372.

37. Salgın-Gökşen, U.; Gökhan-Kelekçi, N.; Göktaş, Ö.; Köysal, Y.; Kılıç, E.; Işık, Ş.; Aktay, G.;

Özalp, M. 1-Acylthiosemicarbazides, 1,2,4-triazole-5(4H)thiones,1,3,4-thiadiazoles and hydrazones containing 5-methyl-2-benzoxazolinones: Synthesis, analgesic-anti-inflammatory and antimicrobial activities. *Bioorg. Med. Chem*. 2007, *15*, 5738–5751.

38. Silva, G.A.; Costa, L.M.M.; Brito, F.C.F.; Miranda, A.L.P.; Barreiro, E.J.; Fraga, C.A.M. New class of potent antinociceptive and antiplatelet 10Hphenothiazine-1-acylhydrazone derivatives. *Bioorg. Med. Chem.* 2004, *12*, 3149–3158.

39. Vicini, P.; Incerti, M.; La Colla, P.; Loddo, R. Anti-HIV evaluation of benzo[d]isothiazole hydrazones. *Eur. J. Med. Chem.* 2009, *44*, 1801–1807.

40. Alptüzün, V.; Taşlı, H.; Erciyas, E. Synthesis and antimicrobial activities of some pyridinium salts. *J. Fac. Pharm, Ankara.* 2006, *35*, 177–188.

41. Douglas, A.W.; Fisher, M.H.; Fishinger, J.J.; Gund, P.; Harris, E.E.; Olson, G.; Patchett, A.A.; Ruyle, W.V. Anticoccidial 1-Substituted 4(1H)-Pyridinone Hydrazones. *J. Med. Chem.* 1977, *20*, 939–943.

42. Hegarty, A.F.; Moroney, P.J.; Scott, F.L. A change from rate-determining bromination to geometric isomerisation of pyridylhydrazones. *J. Chem. Soc. Perkin Trans. 2* 1973, 1466–1471.

43. Vereshchagina, N.N.; Postovskii, I. Trudy Ural'skogo Politekhnicheskogo Instituta im. S. M. Kirova. 1960, *94*, 24–33.

44. Hesse, M.; Meier, H.; Zeeh, B. *Spectroscopic Methods in Organic Chemistry*; Enders, D., Noyori, R., Trost, B.M., Eds.; Georg Thieme Verlag Stuttgart: New York, NY, USA, 1997; p. 212.

45. Clinical and Laboratory Standards Institute (CLSI). Performance standards for antimicrobial susceptibility testing; eighteen informational supplement M100–S18. CLSI, Wayne, PA, USA, 2008.

46. The National Commmittee for Clinical Laboratory Standards (NCCLS). Reference method for broth dilution antifungal susceptibility testing of yeasts; approved standard-second edition, M27-A2. NCCLS, 2002, Wayne, PA, USA.

47. Mann, F.G.; Prior, A.F.; Willcox, T.J. The structure and properties of certain polycyclic indoloand quinolino-derivatives. Part XIII. The cyclisation ofcertain 4-pyridyl- and 4-quinolylhydraxones. *J. Chem. Soc.* 1959, 3830–3834.

48. Comrie, A.M.; Stenlake, J.B. Antituberculosis agens. Part III. Pyridine-4-sulphonamides and – sulphonhydrazides. *J. Chem. Soc.* 1958, 3514–3518.

EARTH SCIENCES

POSSIBILITIES OF ANALYTICAL CONTINUATION OF GRAVITY AND ITS GRADIENTS FOR PREDICTION OF CROSS-SECTION

Isgandarov E.
Associate professor,
Department of "Geophysics" Azerbaijan State Oil and Industrial University (ASOIU), Azerbaijan, Baku
Jafarli L.
Master student,
Department of "Geophysics" Azerbaijan State Oil and Industrial University (ASOIU), Azerbaijan, Baku
DOI: 10.5281/zenodo.19827783

ABSTRACT

This article explores the feasibility of analytically continuing gravity and its gradients for predicting a cross-section. This problem is known to be related to the inverse gravity problem, which is not uniquely solved. To reduce this ambiguity, it is necessary to utilize all a priori information, which can improve the efficiency of solving such a problem. To predict the cross-section of density heterogeneity in rocks based on gravity data, the full normalized gravity gradient is currently used, along with other methods. The Department of Geophysics developed an algorithm and the Force-Fortran program Gnorm, which calculates the full normalized gravity gradient in the lower half-space based on the observed gravity curve at the earth's surface along the profile. This article presents the results of processing model gravity curves to assess the feasibility of cross-section prediction.

Keywords: Gravity curve, Fourier transform, full normalized gradient, density inhomogeneity, number of harmonics.

Introduction

Numerous methods exist for characterizing gravity anomalies and determining the location and depth of anomaly-generating geological features and zones of density heterogeneities based on potential fields. Since the goal of the study is to locate local features in the sedimentary strata at shallow depths, these methods employ differential calculus to enhance the intensity of the potential anomaly from small features. Analytical downward continuation (analytical approximation) can be used to enhance the gravitational influence of features at shallow depths [1,2,13].

Analytical continuation into the lower half-space is a method used to estimate the field closer to the source, resulting in better resolution of rock distribution in subsurface layers. However, the usefulness of this process is limited by its sensitivity to noise, which also leads to false anomalies. After downward continuation, the signal (potential field anomaly) is amplified exponentially proportional to the spectral frequency. In the absence of false anomalies, the analytical continuation process is sufficiently well-defined, and in this case, there is no need to continue below the depth of the geological feature. In filtering terms, this is the use of high-pass filters. In the presence of a false anomaly, the high-frequency amplification is so strong that it almost completely obscures the main useful information. A low-pass Fourier filter can be used to filter out this type of noise. Furthermore, this results in signal blurring, negating the purpose of sharpening the image obtained by the analytical continuation process. Despite the above-mentioned problems, most geophysicists have long been interested in this methodology because it is important for exploration of mineral deposits. Furthermore, this method is a fast and cost-effective way to determine the initial depth of underground objects in areas where logging data is lacking [4].

An effectively executed analytical process of downward continuation can provide accurate information about the subsurface, which can improve interpretation efficiency. Furthermore, analytical continuation into the lower half-space can enhance both the horizontal and vertical components of the potential field anomaly, which can improve the efficiency of solving the geological problem of subsurface subsurface dissection based on density properties.

Finally, models are constructed using a range of modeling programs that incorporate gravity data, and the most appropriate number of harmonics in the Fourier decomposition of the signal is selected. It should be noted that normalizing the total gravity anomaly gradient by the mean value of the total calculated gravity field gradient helps minimize strong field perturbations associated with the downward propagation of gravity anomalies

Means and methods

As is well known, various methods exist for transforming gravity-magnetic data to separate a complex field into regional and local anomalies. Among these methods, the analytical continuation of the potential field into the lower half-space is of interest. The meaning and significance of this method are demonstrated below using computer calculations and graphical plots for examples of gravity field models. Of particular interest is the concept of the full normalized gradient (FNG) method, which involves Fourier transforming the observed gravity curve, analytically continuing it into the lower half-space at various depths, and calculating the full normalized gravity gradient. Using this technique, FNG values can be calculated in the region containing density inhomogeneities corresponding to geological structures. Thus, the two-dimensional FNG curve of gravity anomalies is determined by the following formula (Berezkin, 1973):

$$\mathbf{G}(x,z) = \frac{\sqrt{(g_x(x,z))^2+(g_z(x,z))^2}}{\frac{1}{M}\sum_{i=0}^{M}\sqrt{(g_x(x,z))^2+(g_z(x,z))^2}} \quad (1)$$

where $g_x(x,z) = \frac{\pi}{L}\sum_{n=1}^{N} nB_n \sin\frac{n\pi x}{L} e^{\frac{n\pi z}{L}}$ is the horizontal gradient of gravity at depth z; $g_z(x,z) = \frac{\pi}{L}\sum_{n=1}^{N} nB_n \sin\frac{n\pi x}{L} e^{\frac{n\pi z}{L}}$ is the vertical gradient of gravity at depth z; L is the summation base; N is the maximum number of harmonics; M is the number of points on the base L; n is the coefficient number.

The Geophysics Department of ASOIU developed the Force-Fortran program Gnorm, which calculates the gravity gradient at various depths and was tested using a high-precision profile intersecting the Muradkhanly uplift [3, 6, 8, 10, 11]. In many studies, the number of harmonics (N) is typically determined by trial and error, and the use of additional data, such as drilling data, depends on the problem conditions and data characteristics. In our opinion, it is necessary to use any a priori geological and geophysical information. In addition, it is necessary to consider the intensity and size of the anomaly of the full normalized gravity gradient. In this regard, we performed an analytical continuation of the gravity field of two-dimensional homogeneous cylinder models to their depth [5, 7, 12].

Rezults and discussion

At the beginning, we performed an analytical continuation of the gravity field from the model of a two-dimensional cylinder with a radius of 1 km located at a depth of 4 km using the formula:

$$V_z = \frac{2G\lambda z}{(\xi-x)^2+(\zeta-z)^2}, \quad (2)$$

where G is the gravitational constant; λ is the linear density of the cylinder; z is the depth of the center of a homogeneous cylinder; ξ, ζ are the coordinates of the center of gravity of a horizontal cylinder; x is the abscissa of the point of calculation of V_z on the profile; z is the ordinate of the point of calculation of V_z on the profile.

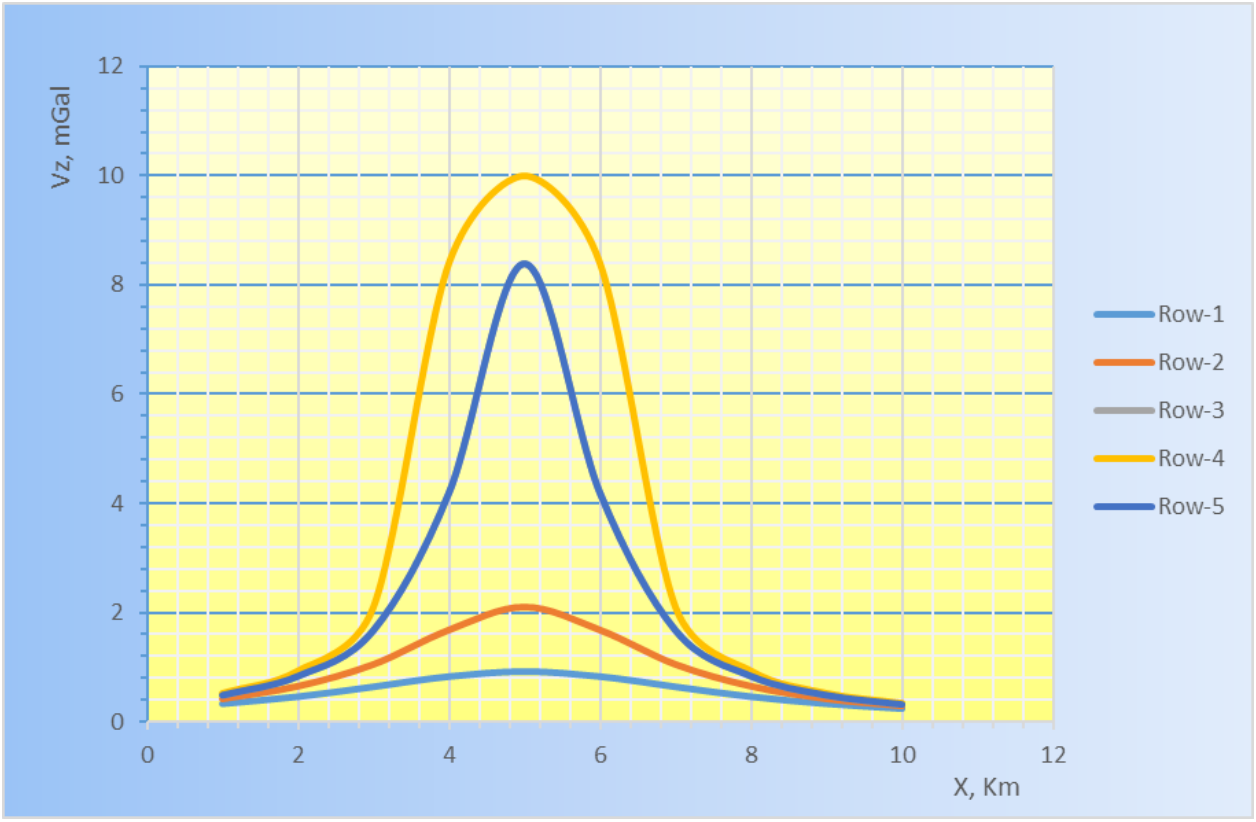
For this purpose, the Force-Fortran program Vzsyl was compiled based on formula (2). The compiled initial data was entered into the Vzsyl program. The results of the analytical continuation of the field from a two-dimensional circular horizontal cylinder model to depths of 1-5 km in mGal units are shown below (Fig. 1). As can be seen, with increasing depth of continuation, the gravity values increase, and at a depth of 4 km ("special point") the value of Vz becomes equal to infinity. Based on the obtained results, gravity curves corresponding to different depths were constructed. The amplitude of the gravity curve corresponding to the depth of the cylinder center was conditionally taken to be equal to 10 mGal (instead of infinity). As can be seen, after passing through the "special point", the values of the gravity curve decrease and therefore the Vz curves at depths of 3 and 5 km coincide (Fig. 2). The same picture is observed in "he diagram we"compiled of the analytical continuation into the lower half-space of the gravity field from a two-dimensional cylinder, which also lies at a depth of 4 km (Fig. 3). Of great interest are the results of our analytical continuation into the lower half-space of the full normalized gravity gradient from a two-dimensional cylinder located at a depth of 4 km. As can be seen in the figure, the full normalized gravity gradient was calculated for a number of harmonics of 10, 20 and 30. The optimal number of harmonics was 30, when the maximum of the total normalized gradient coincided with the cylinder's depth of 4 km. When choosing the optimal number of harmonics, the size and intensity of the total normali'ed gradient must also be taken into account (Fig. 4-7).

MH is the maximum depth of the gravity curve extension in km; X0 and Z0 are the coordinates of the center of gravity of the circular cylinder in km; R is the radius of the cylinder; N is the number of points on the gravity curve profile; AK is the coefficient in the formula for calculating the vertical component of gravity from the cylinder.

MH= 5 X0= 5.0 R= 1.0 Z0= 4.0 N= 10 AK= 8.4

0.34	0.47	0.65	0.84	0.93	0.84	0.65	0.47	0.34	0.25
0.42	0.65	1.05	1.68	2.10	1.68	1.05	0.65	0.42	0.29
0.49	0.84	1.68	4.20	8.40	4.20	1.68	0.84	0.49	0.32
0.52	0.93	2.10	8.40	∞	8.40	2.10	0.93	0.52	0.34
0.49	0.84	1.68	4.20	8.40	4.20	1.68	0.84	0.49	0.32

Fig. 1. Results of analytical extension of the gravity field from a two-dimensional homogeneous cylinder model to depths of 1-5 km



1. *Vz curve at a depth of 1 km; 2- Vz curve at a depth of 2 km; 3- Vz curve at a depth of 3 km; Vz curve at a depth of 4 km; Vz curve at a depth of 5 km (Vz curves at depths of 3 and 5 km coincide).*

Fig. 2. Curves of analytical continuation of the gravity field from the model of a two-dimensional homogeneous cylinder to depths of 1-5 km

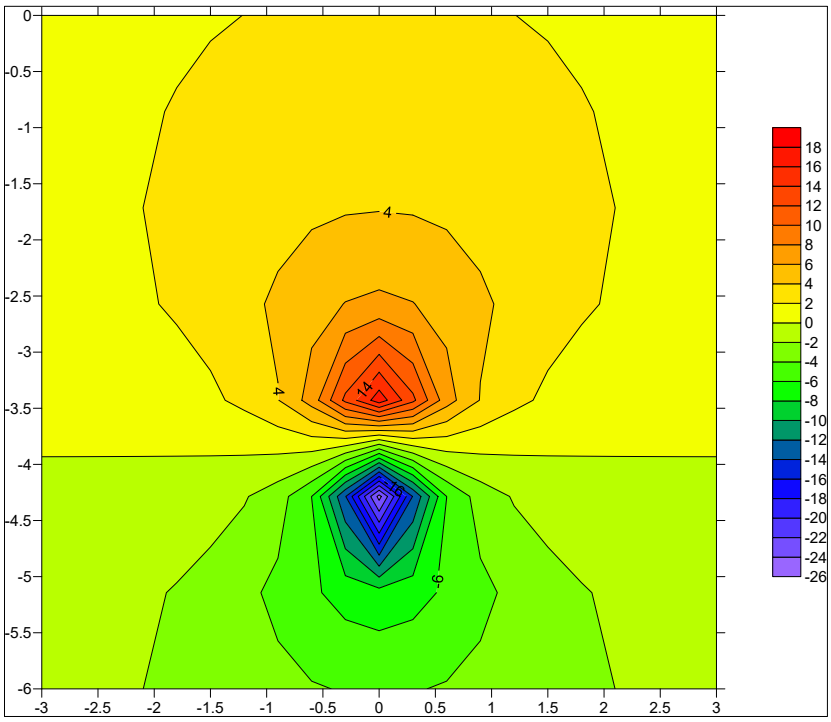


Fig.3. Results of analytical continuation of the gravitational field in the lower half-space

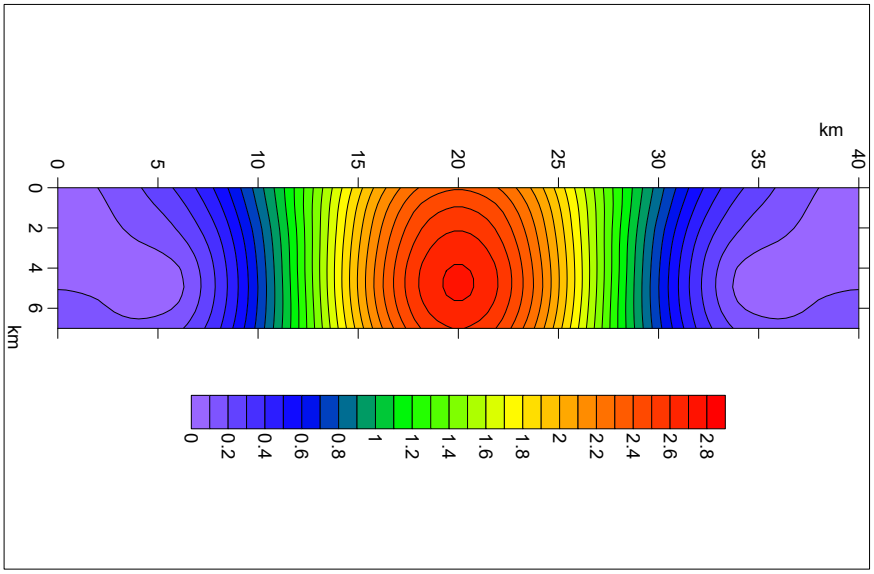


Fig.4. Field of the full normalized gravity gradient from the model of circular cylinder (number of harmonics 10)

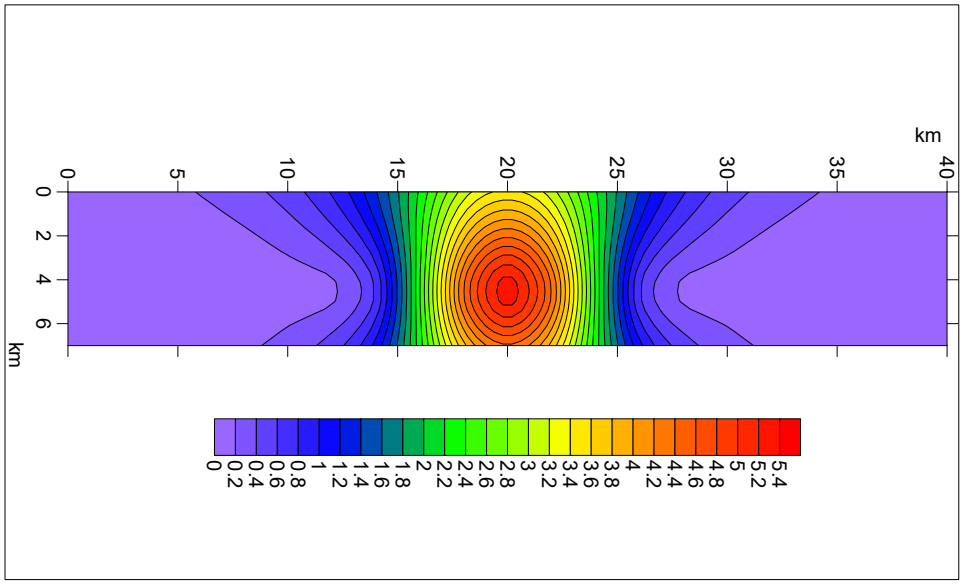


Fig.5. Field of the full normalized gravity gradient from the model of circular cylinder (number of harmonics 20)

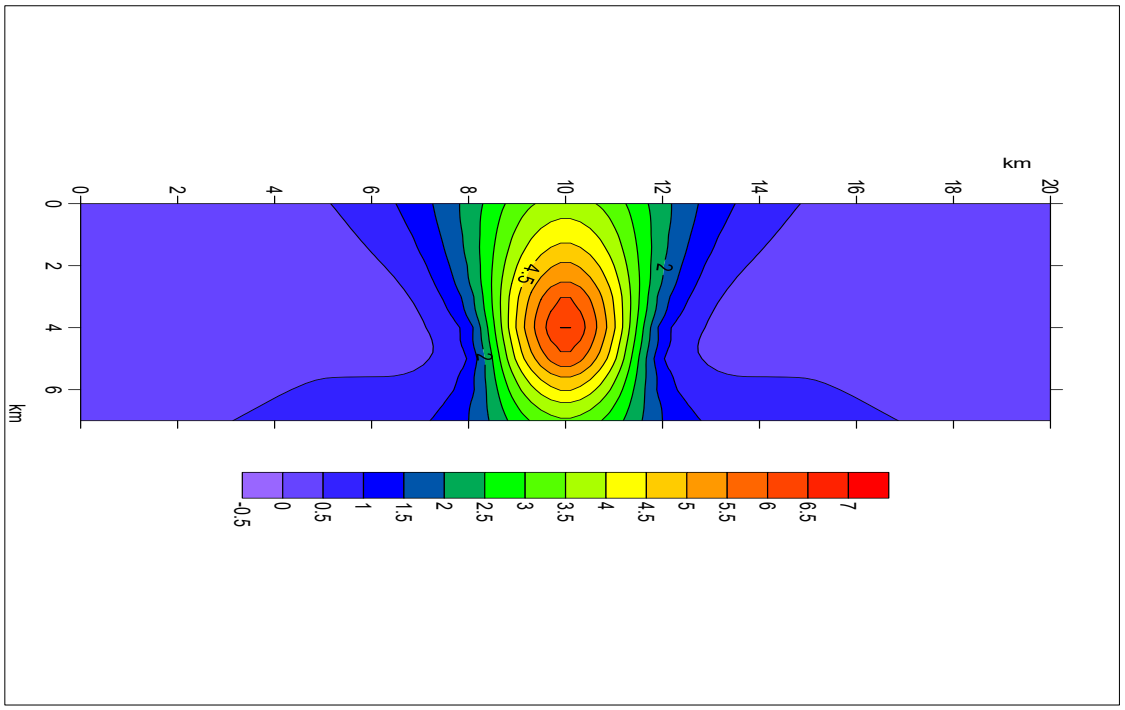


Fig.6. Field of the full normalized gravity gradient from the model of circular cylinder (number of harmonic)

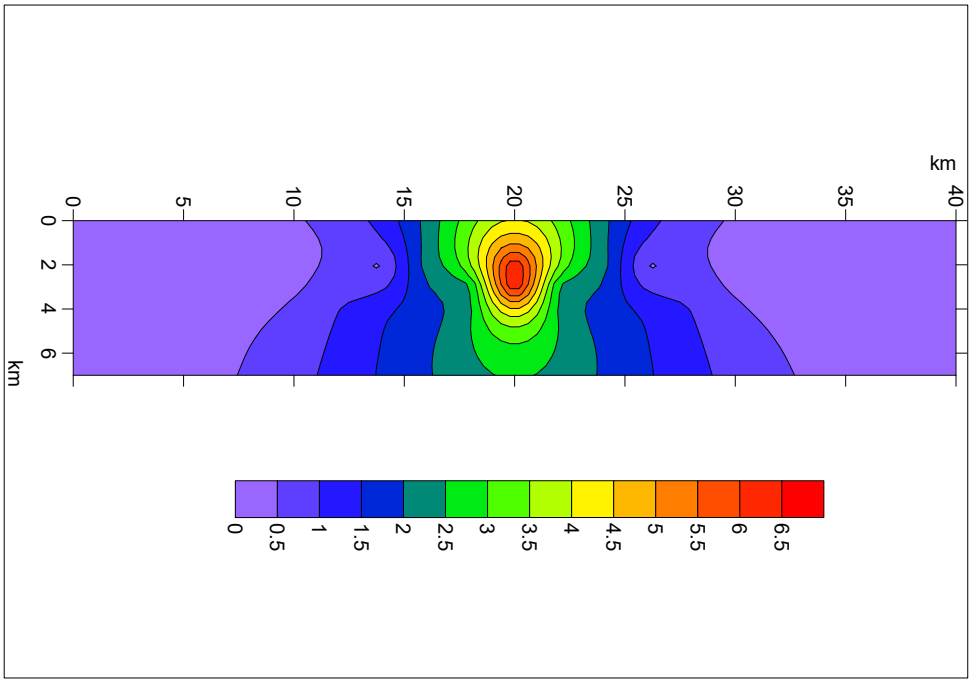


Fig.7. Field of the full normalized gravity gradient from the model of circular cylinder (number of harmonics 30)

Conclusions:

1. An analysis of the analytical continuation of the gravity field into the lower half-space was performed to predict the cross-section of density heterogeneity in rocks. A homogeneous model of a circular horizontal cylinder was created, and the vertical gravity field along the profile was calculated using the Vzsyl program developed in Force- Fortran.

2. Using the Force-Fortran program Vzsyl, an analytical continuation of the Vz curves from a circular horizontal cylinder model to depths of 1–5 km with a 1-km step was performed. The increase in gravity values and the behavior of the gravity field itself as they approach a “special point” are shown.

3. The values of the full normalized gravity gradient at various depths (0-7) km were calculated using the Force-Fortran GNORM program developed at the Department to assess the feasibility of analytically extending the full gravity gradient for predicting density heterogeneity. Using the Surfer program, sections of the full normalized gradient were constructed for different numbers of harmonics in the Fourier decomposition. The optimal number of harmonics was estimated to improve forecast accuracy.

References

1. Berezkin, V.M., The method of full normalized gradient in geophysical exploration. – M.: Nedra, -1988.188 p. (in Russian).

2. Ermokhin, K. M. Analytical continuation of gravitational and magnetic fields through masses. Doklady Earth Sciences, Volume 476, Issue 1, pp. 1054-1057. September 2017. DOI: 10.1134/S1028334X17090021 .

3. Isgandarov E.H. Direct searches of oil and gas deposits according to digital gravity prospecting data. Azerbaijan international geophysics conference. Azerbaijan Geophysics Department, Baku, November 1-3, 2017, 1p. (in Russian).

4. Isgandarov E.H., Talibzadeh O. The basic principle of the fully normalized gradient method and description of its application to gravity anomalies on a 2D synthetic model. GEAD, "Collection of scientific articles of young researchers" dedicated to Victory Day, Baku 2021, p. 110-120. ISBN: 978-9952-8024-1-2.

5. İsgandarov E., Khankishiyev R. Possibilities of analytical continuation of potential fields. Norwegian Journal of development of the International Science, №106/2023, pp.13-18., ISSN 3453-9875, https://doi.org/10.5281/zenodo.7827942

6. İsgandarov E.H. Digital modeling of gravity gradients for solving structural problems and direct hydrocarbons search. XII Azerbaijan International Geophysics Conference "The role of geophysical research in the exploitation of hydrocarbon resources in the caspian region and similar geological provinces" Dedicated to the 100th Anniversary of the birth of National Leader Heydar Aliyev, April 26-28, 2023, p.2.

7. İsgandarov E.H., Nagieva N.B, Isgandarova L.E. Prediction of density heterogeneousity of rocks according to gravity prospecting data. №83, 2024, Slovak international scientific journal, pp.26-33., https://zenodo.org/records/, https://doi.org/10.5281/zenodo.11188943 .

8. İsgandarov Elkhan. Algorithm for computing and digital modeling of the full normalized gradient of the gravity anomaly Azerbaijan National Akademy of sciences. ANAS TRANSACTIONS, EARTH SCIENCES Geology and Geophysics institute. ISSN 2218-8754, 2025, № 1.(Scobus).

10. Iskandarov E.H., Mammadova C.S., Alibeyova Y.T. Prospects of the application of the method of analytical continuation of potential areas in the study of deep-lying and anomalous geological objects. Thesis 5th international conference of young scientists and students, Baku, 2013 p. 221-222. 2 p. (in Russian).

11. İskandarov E.H. Prediction of the presence of hydrocarbon deposits in deep-seated volcanic-sedimentary formations of the Mesozoic using high-precision gravity survey. Mater. Scientific those. Conf. geologist-geophysicist. Methods of search and reconnaissance of places. N. and g. at great depths, Baku, 1984, p.57-59 (in Russian).

12. İskandarov Elkhan and Seyidov Vagif. Digital modeling of analytical continuation of gravitational field. German İnternational Jornal of Modern Science

13. Tsimelzon I.O., Amiraslanov T.S., Iskandarov E.H. Separation of gravitational and magnetic fields by the method of complete normalized gradient in a three-dimensional version. News of universities Oil and gas, 1989, No. 10, pp. 3-6 (in Russian).

ECONOMIC SCIENCES

ANALYSES OF TAX STRUCTURE AND ECONOMIC GROWTH

Sherifov O.
Master of Khazar University
DOI: 10.5281/zenodo.19827820

ABSTRACT

This study examines the impact of tax structure on economic growth and investment dynamics, focusing on how different types of taxation influence key macroeconomic indicators such as Gross Domestic Product (GDP), investment levels, and consumption patterns. The research highlights that taxation plays a dual role in economic systems: while it provides essential public revenues for financing infrastructure, education, and technological development, it can also impose constraints on private sector activity if designed inefficiently. The paper analyzes the effects of income taxes, corporate taxes, and consumption-based taxes, demonstrating that high tax burdens may negatively affect investment incentives and labor supply, whereas well-structured tax systems can support sustainable economic growth.

Empirical analysis based on correlation and regression models indicates that investment has a strong positive relationship with GDP growth, while excessive taxation shows a moderate negative effect. However, the findings also reveal that consumption taxes such as value-added tax (VAT) have a less distortive impact on economic performance compared to income-based taxes. Additionally, government expenditure financed through tax revenues—particularly in infrastructure and human capital—plays a crucial role in enhancing long-term productivity and economic stability.

The study further emphasizes the importance of tax policy design, institutional quality, and fiscal efficiency in shaping economic outcomes. Comparative analysis across different economic models suggests that balanced tax systems, combined with effective public spending, can achieve both economic growth and social equity. The results provide important policy implications, indicating that governments, particularly, should prioritize efficient tax structures, promote investment-friendly environments, and ensure transparency and stability in fiscal policy to foster sustainable economic development.

Keywords: Tax structure, Economic growth, GDP, Investment, Fiscal policy, Tax incentives, Public expenditure, VAT, Economic development, Tax policy.

Introduction. Economic growth is affected by taxes, which is a common occurrence in national economic policy and national financial systems. Taxes serve as the most significant method that the government applies to generate funds for public spending, and the general economic development of an economy can be assessed by the growth of Gross Domestic Product (GDP). The impact of taxes on economic growth has a critical impact on the national tax systems that the policymakers develop to facilitate economic growth without the addition of unnecessary expenses to the existing economic activities. Taxation impacts the GDP growth by affecting consumption and investment and labor supply, and productivity. The taxes imposed by the government on the income of individuals and the profits, and the consumption rates may cause the disposable income of households to reduce and consume business resources. This affects the behavior of the individuals about spending and saving, and investment. High taxation rates deprive of economic participation and discourage new business persons to invest in the economy and the economic growth is decelerated. Sensible and appropriate tax systems generate sufficient revenue to fund infrastructure and education, and healthcare, and technological innovation to support long-term economic development.

Taxes influence the economic expansion mainly via private investment. The profitability of business activities is directly influenced by corporate taxes and capital gains taxes. The increase in corporate tax rates may result in reduced after-tax profits that discourage companies from expanding, hiring, and investing in new technologies. Reducing corporate taxes or offering tax incentives will stimulate investment and achieve higher productivity, which will eventually increase GDP growth. The majority of the countries provide tax incentives to research and development, innovation, and strategic industries to enhance their economic competitiveness. Tax influence on labor markets is another significant factor. Payroll and income taxes affect the working, saving and skill-acquiring decisions of the people. When the marginal tax rates are high, the interest to work more or be in the labor force reduces, resulting in a negative impact on the productivity of the economy. Progressive income tax systems are commonly utilized to create social fairness and to decrease the level of income disparity. Such systems can be used to harmonize economic efficiency with social welfare objectives when they are designed appropriately. Government expenditure on tax-financed spending has a significant impact on GDP growth. Infrastructure, transport, digital technology and education infrastructure can enhance the output levels and provide conducive growth environment for private businesses. The investment of funds creates a positive economic impact because it creates additional work for people, increased sales of products and services and the advancement of technology.

Methodology. This study adopts a rigorous quantitative research design to examine the impact of tax structure on economic growth and investment dynamics. The empirical analysis is based on secondary data

obtained from internationally recognized databases, primarily the World Bank. The dataset includes key macroeconomic indicators such as GDP growth rate, total tax revenue as a percentage of GDP, corporate tax rates, consumption taxes (value-added tax, VAT), investment rates, and public infrastructure expenditure. The study utilizes panel data covering multiple countries with different economic structures to enable cross-country comparisons and improve the generalizability of findings.

To explore the relationships between variables, the study first applies descriptive statistical analysis to identify general trends and patterns in taxation and economic performance. This is followed by a correlation analysis, which measures the strength and direction of the relationships between tax variables and economic growth indicators. The correlation matrix provides initial insights into the associations between GDP growth, tax burden, investment levels, and consumption.

The regression model is estimated using Ordinary Least Squares (OLS) techniques. Statistical significance is evaluated using t-statistics and p-values, while model validity is assessed through standard diagnostic tests, including multicollinearity, heteroskedasticity, and model specification checks.

In addition, a comparative analytical approach is applied to examine differences across economic systems, including liberal market economies, mixed economies, and social welfare economies. This allows for evaluating how variations in tax structures and fiscal policies influence economic performance, investment behavior, and income distribution.

Finally, the study incorporates a policy-oriented analytical framework to interpret empirical findings in the context of fiscal policy design. The results are used to derive evidence-based policy recommendations aimed at optimizing tax structures to promote sustainable economic growth, enhance investment activity, and ensure macroeconomic stability.

Literature Review. The relationship between taxation and economic growth has been widely examined in both theoretical and empirical economic literature. Existing studies highlight that tax policy plays a critical role in shaping macroeconomic performance through its influence on investment, consumption, labor supply, and income distribution. However, the direction and magnitude of this relationship remain subject to debate, largely depending on the structure of the tax system, institutional quality, and fiscal policy effectiveness.

Recent empirical studies emphasize the differentiated impact of various types of taxes on economic growth. For instance, Balasoiu, N. et al. (2023) provide evidence from European Union countries showing that direct taxes tend to have a negative effect on economic growth, primarily due to their distortionary impact on investment and labor incentives. Similarly, Angelov, A. and Nikolova, V. (2025) confirm a causal relationship between direct tax burden and slower economic growth in countries with proportional taxation systems. These findings are consistent with earlier theoretical contributions suggesting that high income and corporate taxes reduce economic efficiency and capital accumulation.

In contrast, consumption-based taxation is often associated with more favorable economic outcomes. Sun, L. and Nishigaki, Y. (2025) demonstrate that consumption taxes, such as value-added tax (VAT), have a less negative impact on economic growth and may even contribute positively by supporting human capital development and income redistribution. This aligns with the broader consensus in economic theory that consumption taxes are less distortive compared to income-based taxes.

The role of tax pressure and fiscal burden in shaping long-term economic performance has also been explored in emerging economies. Benkejjane, N. et al. (2024) find that excessive tax pressure can hinder long-term economic growth in Morocco, particularly when it discourages private sector activity. Similarly, Sakar, E. et al. (2025) highlight the Importance of tax revenue structure and policy uncertainty in G7 economies, concluding that stable and predictable tax systems are essential for sustaining economic growth.

Another important strand of literature focuses on the role of government expenditure financed through taxation. Menguy, S. (2025) argues that the share of public expenditure in GDP can have both positive and negative effects depending on its efficiency and allocation. Productive expenditures, particularly in infrastructure and education, tend to enhance economic growth, while inefficient spending may reduce overall productivity. This perspective is supported by Fortea, C. (2025), who finds that the structure of government revenue significantly affects fiscal performance and economic outcomes in developed economies.

Corporate taxation and its implications for investment and profitability have also received significant attention. Andrejovská, A. and Glova, J. (2023) identify key economic determinants influencing corporate tax revenues, emphasizing the interaction between tax policy and business cycles. Additionally, Rachidi, M. and El Moudden, A. (2025) provide evidence on profit-shifting behavior, suggesting that differences in corporate tax rates across countries influence multinational firms' investment decisions and profitability.

The interaction between taxation and macroeconomic stability has been explored using advanced econometric and theoretical models. Panzaru, C. et al. (2025) apply a dynamic IS–LM framework to show that delayed taxation policies can influence macroeconomic stability and growth trajectories. Similarly, Che, S. et al. (2021) analyze land taxation and conclude that well-designed tax systems can support sustainable economic growth by improving resource allocation.

In the context of globalization and structural transformation, tax policy has become an essential tool for promoting competitiveness and sustainable development. Wang, Y. et al. (2025) demonstrate how production tax policies can simultaneously affect economic growth and environmental sustainability. Likewise, Quispe-Espinoza, E. P. et al. (2025) highlight the role of tax legislation in supporting sustainable economic growth in emerging markets, particularly through land management and regulatory frameworks.

Several studies also emphasize the broader socio-economic implications of taxation. Hira, A. et al.

(2026) argue that tax policy must balance growth and equity objectives, as excessive redistribution may weaken economic incentives, while moderate redistribution can enhance social stability and long-term growth. Similarly, Bajrami, R. et al. (2025) link economic freedom, including tax policy, to improved economic performance in transition economies.

Earlier and regional studies, particularly in Russian-language literature, provide additional insights into the taxation-growth nexus. Researchers such as Juravlev T.A. (2007) and Animisov S.A. (2012) emphasize the importance of tax burden optimization in achieving sustainable economic growth. More recent contributions, including S.Valentovich and Pavlovich (2024), focus on tax stimulation mechanisms and their role in post-crisis economic recovery.

Overall, the literature suggests that the impact of taxation on economic growth is not uniform but depends on multiple interacting factors. While high tax burdens, particularly direct taxes, may hinder investment and growth, efficient tax structures combined with productive public spending can enhance long-term economic performance. The consensus across studies highlights the importance of balanced tax systems that minimize distortions while ensuring adequate revenue generation for sustainable development.

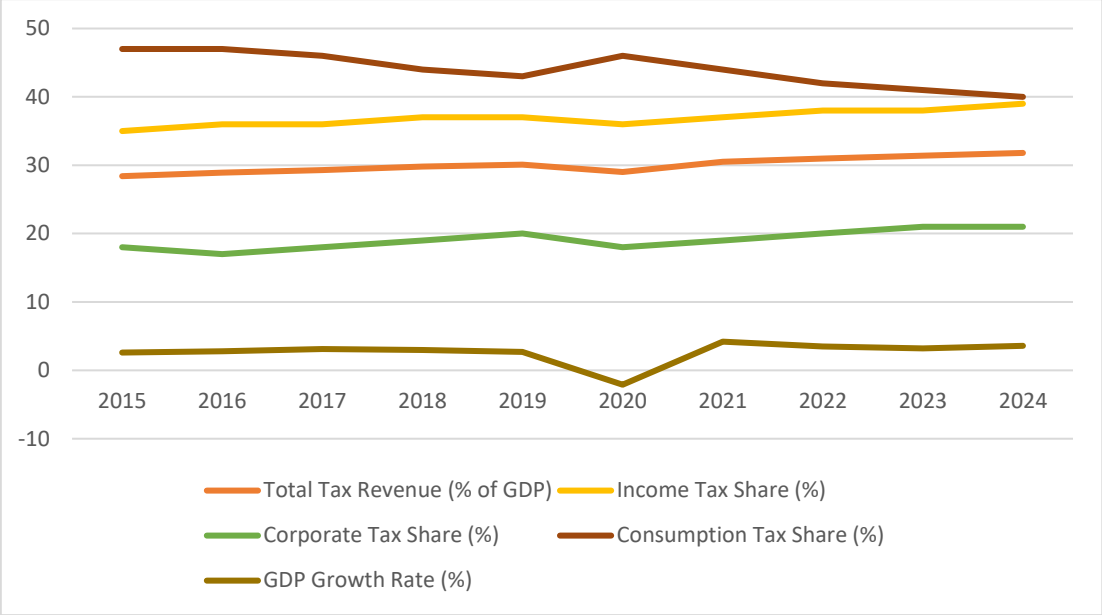
Emprical analyses and discussion. The empirical research on the effects of taxation on GDP growth produces inconsistent results due to the fact that the relationship between the two variables depends on multiple factors including the design of the tax system and the stage of economic development and institutional strength and fiscal policy decisions. The value-added tax (VAT) as a consumption tax imposes a smaller negative effect on investment than income and capital taxes. The efficient use of tax revenue for productive public spending creates a positive impact on long-term economic expansion. Tax administration and compliance affect the relationship of taxes to GDP growth. Good tax collection system prevents low taxes, and generates more income to the government. The digital administration of taxes, transparency and institutional framework development can strengthen the fiscal capability and the economic development. Globalization has made it necessary for nations to revisit their taxation policies as they affect the international business competitiveness and foreign direct investment. The countries that have uniform tax systems and fair tax charges and open laws will normally have higher international investment. International business organizations normally take into consideration the corporate tax rates and fiscal benefits when making decisions regarding the location of their production centers and regional headquarters. This creates a situation where governments can be able to maintain their domestic fiscal needs at the same time since they have to maintain a viable economic environment to be able to conduct international trade.

The impact of taxes on GDP growth also depends on how the tax system is designed. Economic performance is affected differently by the way taxes are imposed, whether through income or consumption or property taxes. Most economists believe that consumption-based taxes such as sales taxes or value-added tax (VAT) have a smaller adverse effect on economic growth than income and corporate taxes. Consumption taxes do not have an immediate impact on reducing the motivation to save or invest money which are the key elements for capital formation and long-term economic development. On the same note, taxes on profits and personal income contribute to the decision-making process of the individuals regarding their investment and also reduce the level of productivity. High tax rates eliminate the new business ideas and also expansion. The high tax rate of the wage discourages people to work extra or play a full-time role in the labor market. This is why the legislators aim at a balanced tax system. They work to maintain the revenue but reduce the negative behaviors in the economy.

The effectiveness of government expenditure that is financed with tax funds is one of the key elements that affect the way taxes affect the growth of GDP. Tax revenue that is used in productive investments such as building infrastructure and education and science research and healthcare systems could have a positive impact on the economic productivity and human capital development. The fundings that we mention in the paper provide the base for sustainable economic growth, as they contribute to the development of the labor force, advancement of technological innovation and efficiency in the economic activities. Another influence on the relationship between taxation and economic growth is fiscal stability and policy predictability. Firms and investors generally prefer to work in countries where the tax laws are clear and stable, and they can easily predict what their future tax liabilities will be. When tax regulations are subject to frequent modifications or when there is uncertainty about the future levels of tax impositions, it will drive away the long-term investments and dent economic confidence. A stable and well-regulated tax system helps create a good investment environment and supports sustainable economic development. Taxation in income equality reduction has a direct influence on GDP expansion. Progressive tax systems allow governments to distribute income and provide social programs to help disadvantaged individuals in the population. Tax inequality distribution requires a delicate balance because too much redistribution reduces employment incentives but moderate redistribution creates social stability and economic expansion. The government needs progressive tax funding to provide educational and healthcare programs which enhance workforce productivity.

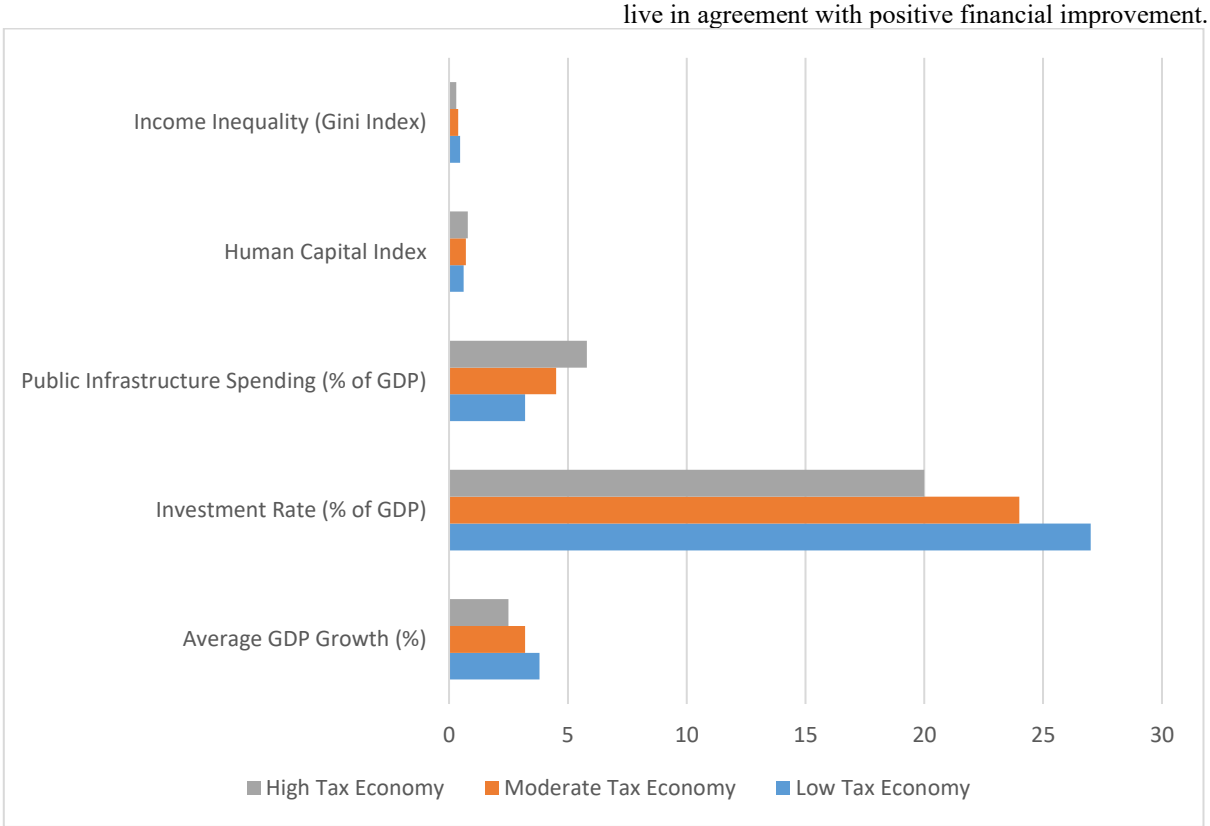
Tax policy is an effective tool to promote structural changes and the development of the economy in emerging markets. Governments may utilize particular tax incentives to encourage investment in the manufacturing, renewable energy, IT, and digital infrastructure sectors. The application of tax policy contributes to the diversification of economic activities, the growth of exports, and the Improvement of the national competitiveness in the international market. Globalization creates a complex link between taxation and GDP growth rates. Global mobility of capital enables companies and investors to shift their business operations to countries

that provide them with better tax benefits. The government authorities must create tax systems that enable them to generate substantial domestic revenue while drawing in foreign direct investment. International cooperation has developed into a vital instrument that enables countries to fight against multinational tax avoidance and profit shifting activities.



Graphic 1. Tax Revenue Structure and GDP Growth Dynamics
Source: www.worldbank.org (Created by Authors)

The data demonstrates that sales burden is the largest portion of the tax revenues in most years, and the vital pay and business taxes represent smaller proportions. In the time of money related shocks such as the 2020 around the world crisis, the GDP advancement diminished, and there was a brief diminish in charge income. The taking after a long time showed cash related recovery, where the GDP advancement extended, and there were direct additions in charge income. The data proposes that a strong and balanced work structure can live in agreement with positive financial improvement.



Graphic 2. Tax Policy Structure and Economic Performance Indicators
Source: www.worldbank.org (Created by Authors)

The analysis shows that countries with lower tax rates tend to demonstrate higher short-term GDP growth and investment rates, as businesses and individuals face fewer financial constraints. However, economies with higher tax levels often allocate more resources to public infrastructure, education, and social services, which can improve human capital development and reduce income inequality. For instance, the human capital index is highest in high-tax economies, reflecting stronger investment in education and healthcare systems. Similarly, income inequality is significantly lower in these countries due to redistributive fiscal policies.

Table 1

Correlation Between Tax Burden and GDP Growth

Variable	**GDP Growth Rate**	**Tax Revenue (% of GDP)**	**Investment Rate (% of GDP)**	**Consumption Level**
GDP Growth Rate	1.00	-0.32	0.58	0.41
Tax Revenue (% of GDP)	-0.32	1.00	-0.27	-0.15
Investment Rate (% of GDP)	0.58	-0.27	1.00	0.36
Consumption Level	0.41	-0.15	0.36	1.00

The correlation matrix presented in Table 1 illustrates the statistical relationships between taxation indicators and economic growth variables. The results show that GDP growth has a moderate positive correlation with investment rate (0.58), indicating that increased investment contributes significantly to economic expansion. At the same time, the relationship between GDP growth and tax revenue as a percentage of GDP is slightly negative (-0.32), suggesting that higher tax burdens may moderately reduce economic growth if they negatively affect investment incentives. The results also demonstrate that consumption levels positively influence GDP growth (0.41), reflecting the importance of domestic demand in economic development. These findings confirm that taxation policies must be designed carefully in order to avoid excessive pressure on investment and consumption activities.

Table 2

Regression Analysis of Taxation Impact on GDP Growth

Independent Variables	Coefficient	Standard Error	t-Statistic	Significance Level (p-value)
Tax Revenue (% of GDP)	-0.28	0.09	-3.11	0.004
Corporate Tax Rate	-0.21	0.07	-2.84	0.009
Consumption Tax (VAT)	0.15	0.06	2.33	0.024
Public Infrastructure Spending	0.37	0.11	3.36	0.002
Constant	1.85	0.54	3.42	0.001

Table 2 presents the results of a regression analysis examining how different tax-related variables influence GDP growth. The negative coefficient for total tax revenue (-0.28) suggests that excessive tax burdens may slightly reduce economic growth by discouraging private investment and business expansion. Similarly, higher corporate tax rates show a negative relationship with GDP growth (-0.21), indicating that heavy taxation on businesses may reduce incentives for productive investment. However, the results also demonstrate that consumption taxes such as VAT may have a positive effect on economic growth (0.15), as they generally distort investment decisions less than income-based taxes. Additionally, public infrastructure spending shows the strongest positive coefficient (0.37), highlighting the importance of productive government expenditures financed by tax revenues.

These findings suggest that the structure and allocation of taxes play a more significant role than the absolute level of taxation. Tax revenues used efficiently for infrastructure, education, and innovation can contribute positively to long-term economic development.

Table 3

Comparative Analysis of Tax Systems and GDP Growth in Different Economic Models

Economic Model	Average Tax Burden (% of GDP)	Average GDP Growth (%)	Investment Level (% of GDP)	Income Inequality (Gini Index)
Liberal Market Economies	24	3.7	28	0.43
Mixed Economies	30	3.1	25	0.36
Social Welfare Economies	36	2.6	22	0.29

Source: **Source: www.worldbank.org (Created by Authors)**

Table 3 compares different economic systems in terms of tax burden, GDP growth, investment levels, and income distribution. Liberal market economies tend to maintain lower tax burdens and higher GDP growth rates due to strong private sector investment and entrepreneurial activity. However, these economies also tend to exhibit higher income inequality. Mixed economies maintain moderate tax levels and balanced

economic growth, while social welfare economies typically have higher taxation levels to support extensive public services and social protection programs. Although GDP growth may be slightly lower in such systems, these countries often achieve lower income inequality and higher human development indicators. The comparison indicates that the relationship between taxation and economic growth is not purely linear. Instead, the effectiveness of taxation depends largely on fiscal policy design, institutional quality, and the efficiency of government spending.

Tax policy forms a vital component which determines the economic progress of a nation through affecting investment and consumption and income distribution and the ability of the government to finance public services. The tax systems are utilised by the governments to generate revenue but also to guide economic activity and to attain broader social and developmental goals. When tax policy is developed well, it result to sustainable development of the economy and social stability and enhancement of living standards. Revenue law helps to create financial assets that may be used in public investment as part of economic development. The governments collect taxes from individuals and businesses to fund essential sectors such as infrastructure, education, healthcare, and technological advancement. Improved transportation, digital infrastructure, enhanced energy systems, and advanced communication technology lead to increased productivity and economic growth through business facilitation.

Public funding of investments through taxes hit the economy to generate business-friendly environments that increase private sector growth and increase the general efficiency of the economy. Tax policy affects how firms make decisions regarding the use of their capital and the expansion or contraction of their business units. Depreciation of corporate taxes, additional fiscal benefits, and enhanced allowances reduce costs and revenues for firms, and this directly affects the market behavior of firms and individual investors. Governments normally provide specific tax benefits to stimulate investment in high priority sectors that include production, renewable energy, technology and research and development. These incentives add revenue to the country and decrease innovation and result in products being produced by numerous manufacturers, and the economy of the nation becomes more varied. A strategic approach is applied by the emerging nations by utilizing tax policy to promote industrialization and the advancement of technology in the nation. Tax policy also helps an essential part in economic growth since it redistributes income and reduces economic inequality. The government receives more money through progressive tax systems from the richer individuals and businesses and at the same time provides social support to the poor.

Graphic 3. The Role of Taxation in Promoting Economic Growth

The revenue from taxes is used to fund social programs which include healthcare and education and pensions and poverty eradication programs. Social welfare programs are known to increase the level of social welfare and establish equal chances of economic participation. Tax policy also influences macroeconomic stability. The government can change the taxes by fiscal policy operations to keep the economy stable during economic ups and downs. The government can reduce taxes during economic downturns with a view of stimulating consumption and investment. The government may introduce higher taxes during the time of high economic growth to decrease inflation and maintain fiscal stability. A countercyclical tax policy is used to sustain the economy and contributes to long-term economic development. Also, tax policy is a contributor to the formalization of economic activities. A good tax administration system encourages people and businesses to make their business deals in the formal economy and this improves transparency and accountability. The government may generate more revenue in the form of stable revenues through a wider tax base without having to charge very high tax rates. Formalization also reinforces the financial systems, enhances the credit access of enterprises, and enhances the overall economic governance.

Tax policy has a great contribution to economic development, especially in the present world which is

globalized and digitally transformed. The governments have to make sure that their tax systems are competitive and also ensure that multinationational corporations and online firms are fairly taxed. There needs to be more international cooperation and modern tax rules to ensure that firms do not evade taxes and shift profits across borders. Additionally, it is now possible to find environmental and sustainability aspects in contemporary tax policies. To achieve sustainable economic growth, most governments have implemented environmental taxes, carbon taxes, and tax breaks on green technologies.

Table 4

Tax Policy Indicators and Economic Development Outcomes

Indicator	Developing Economies	Emerging Economies	Developed Economies
Average Tax Revenue (% of GDP)	18	24	34
GDP Growth Rate (%)	4.2	3.5	2.1
Public Infrastructure Investment (% of GDP)	3.1	4.3	5.2
Education Spending (% of GDP)	3.5	4.8	6.1
Human Development Index (HDI)	0.63	0.75	0.89

Source: www.worldbank.org (Created by Authors)

Table 4 presents the relationship between tax revenue levels and economic development indicators across different groups of countries. The data shows that developed economies generally collect higher tax revenues relative to GDP. These higher tax revenues allow governments to invest more in infrastructure, education, and social services, which contributes to higher human development indicators. Developing economies tend to have lower tax revenue levels due to narrower tax bases and weaker tax administration systems. Although these economies may experience relatively higher GDP growth rates due to structural transformation and industrial expansion, limited public investment can constrain long-term economic development.

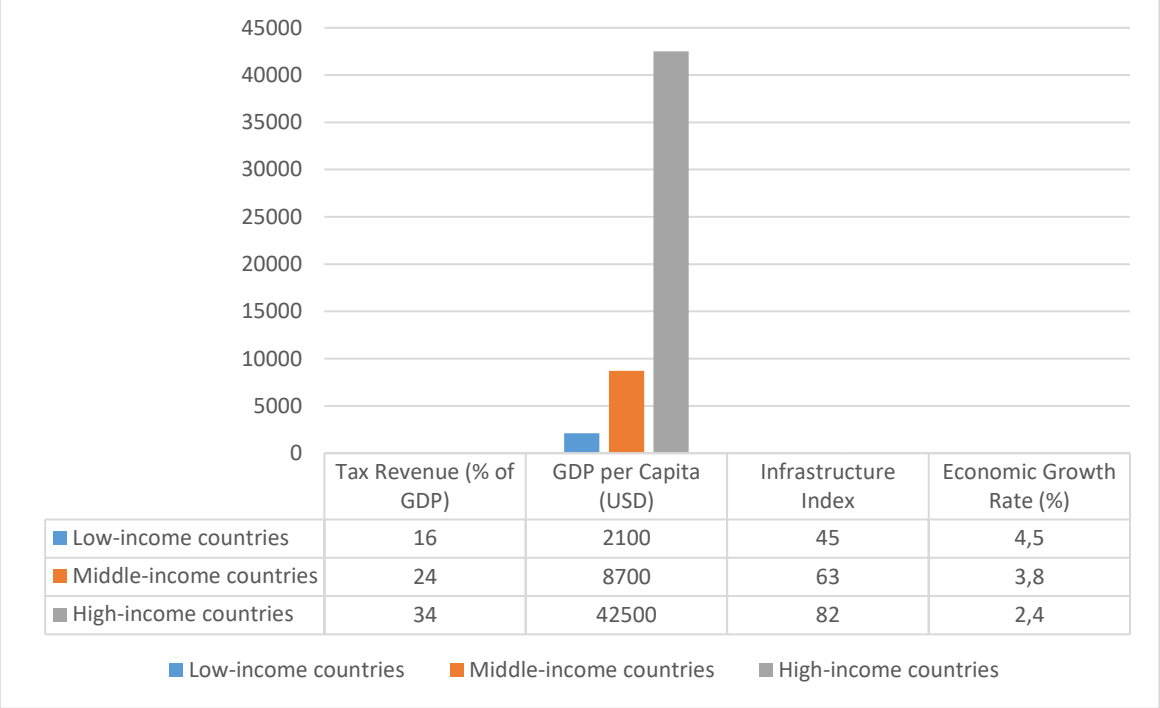
Table 5

Impact of Tax Incentives on Investment and Economic Growth

Type of Tax Incentive	Investment Growth (%)	Employment Growth (%)	Contribution to GDP Growth (%)
Corporate Tax Reduction	8.4	5.6	1.8
Investment Tax Credits	10.2	6.1	2.3
Research & Development Tax Incentives	12.7	4.3	2.6
Export Tax Incentives	9.5	5.0	2.0

Source: www.worldbank.org (Created by Authors)

Table 5 demonstrates the potential impact of different tax incentives on economic performance indicators. Research and development tax incentives show the strongest effect on GDP growth and investment expansion, highlighting the importance of innovation-driven economic policies. Investment tax credits also significantly increase capital formation and employment growth by reducing the cost of new investments for businesses.



	Tax Revenue (% of GDP)	GDP per Capita (USD)	Infrastructure Index	Economic Growth Rate (%)
Low-income countries	16	2100	45	4,5
Middle-income countries	24	8700	63	3,8
High-income countries	34	42500	82	2,4

Graphic 4. Tax revenue, GDP per capita, infrastructure index, growth.
Source: www.worldbank.org (Created by Authors)

Graphic 4 presents a comparative analysis of tax revenue levels and economic development indicators across different groups of countries. The data illustrates that high-income countries typically collect a larger share of tax revenues relative to their GDP compared to developing economies. This higher level of tax collection allows governments in developed economies to allocate greater resources toward infrastructure development, public services, and technological advancement.

Although developing countries often experience higher economic growth rates due to industrial expansion and economic transformation, their limited tax revenue capacity can restrict their ability to finance long-term development programs. Emerging economies demonstrate intermediate levels of tax revenue and economic growth, reflecting their transitional stage between developing and developed economic structures. Overall, the table suggests that higher tax revenue levels, when efficiently managed, contribute to improved infrastructure and broader economic development outcomes.

Results

The empirical findings of this study provide important insights into the relationship between tax structure, economic growth, and investment dynamics. The results obtained from correlation and regression analyses indicate that the impact of taxation on economic performance is multifaceted and depends largely on the composition of the tax system and the efficiency of public expenditure.

The correlation analysis reveals a moderate positive relationship between investment and GDP growth ($r = 0.58$), confirming that capital formation remains a key driver of economic expansion. In contrast, the relationship between total tax revenue and GDP growth is found to be negative but relatively weak ($r = -0.32$), suggesting that higher tax burdens may slightly constrain economic activity, particularly when they reduce incentives for private investment. Additionally, consumption shows a positive association with GDP growth ($r = 0.41$), highlighting the importance of domestic demand in supporting economic performance.

The results of the regression analysis further clarify these relationships. The coefficient for total tax revenue (% of GDP) is negative and statistically significant ($\beta = -0.28$, $p < 0.01$), indicating that excessive taxation may hinder economic growth by discouraging business expansion and reducing investment incentives. Similarly, corporate tax rates exhibit a negative impact on GDP growth ($\beta = -0.21$, $p < 0.01$), suggesting that higher taxation on corporate profits reduces after-tax returns and limits capital accumulation.

In contrast, consumption-based taxation, particularly value-added tax (VAT), demonstrates a positive and statistically significant relationship with economic growth ($\beta = 0.15$, $p < 0.05$). This finding supports the argument that consumption taxes are less distortive than income-based taxes, as they do not directly discourage savings and investment decisions.

One of the most notable findings is the strong positive effect of public infrastructure spending on economic growth. The regression results show that infrastructure expenditure has the highest positive coefficient ($\beta = 0.37$, $p < 0.01$) among all variables, emphasizing the critical role of productive government spending in enhancing economic performance. This suggests that the negative effects of taxation can be mitigated when tax revenues are efficiently allocated to growth-enhancing sectors such as infrastructure, education, and technological development.

The comparative analysis across different economic models further supports these findings. Economies with lower tax burdens tend to achieve higher

short-term GDP growth and investment rates, driven by stronger private sector activity. However, economies with higher tax levels demonstrate better performance in terms of income equality and human capital development, due to increased public spending on social services. This indicates that the relationship between taxation and economic growth is not linear, but rather depends on the balance between efficiency and equity objectives.

Overall, the results demonstrate that:

- The structure of taxation is more important than the absolute level of taxes.
- High corporate and income taxes tend to negatively affect investment and growth.
- Consumption taxes have a relatively neutral or positive impact on economic performance.
- Efficient allocation of tax revenues, particularly toward infrastructure and human capital, significantly enhances economic growth.

These findings highlight the importance of designing balanced and efficient tax systems that support both economic growth and social welfare, while minimizing distortions in investment and labor market behavior.

References

1. Balasoiu, N., Chifu, I., & Oancea, M. (2023). Impact of Direct Taxation on Economic Growth: Empirical Evidence Based on Panel Data Regression Analysis at the Level of Eu Countries. Sustainability, 15(9), 7146. https://doi.org/10.3390/su15097146
2. Sun, L., & Nishigaki, Y. (2025). Effect of Comprehensive Income and Consumption Taxes on Human Capital, Economic Growth, and Income Distribution: Endogenous Economic Growth and Empirical Evidence. Economies, 13(7), 201. https://doi.org/10.3390/economies13070201
3. Angelov, A., & Nikolova, V. (2025). Causality Between the Tax Burden of Direct Taxes and Economic Growth in European Union Countries with Proportional Taxation. Journal of Risk and Financial Management, 18(11), 626. https://doi.org/10.3390/jrfm1811062
4. Benkejjane, N., Mhatchan, S., Oudgou, M., & Boudhar, A. (2024). The Impact of Tax Pressure on Long-Term Economic Growth in Morocco. Economies, 12(8), 201. https://doi.org/10.3390/economies12080201
5. Sakar, E., Sasmaz, M. U., & Ozen, A. (2025). The Nexus Between Tax Revenue, Economic Policy Uncertainty, and Economic Growth: Evidence from G7 Economies. Sustainability, 17(15), 6780. https://doi.org/10.3390/su17156780
6. Menguy, S. (2025). How Harmful Is a High Share of Public Expenditure in GDP? Economies, 13(3), 74. https://doi.org/10.3390/economies13030074
7. Alirzayev, E., & Huseynova, S. (2025). Empirical Evidence Of J-Curve Effect And Marshall Lerner Condition: Case Of Azerbaijan. *The Scientific-Analytical Journal" Economic Reforms"*, *2025*(1), 40-56.
8. Huseynova, S. M., & Quliyev, A. (2025). Current Development Megatrends and Perspective Directions of Green Tourism in Azerbaijan. *Problemy Ekonomiky*, (4), 33-39.
9. Sara M. Huseynova, & Telman J. Hajizada (2024). Analysis of the Stability of the Banking Sector of Azerbaijan in Conditions of Economic Crisis Based on the Econometric Model. Статистика и экономика, 21 (2), 35-49. Doi: 10.21686/2500-3925-2024-2-35-49
10. Huseynova, S. M., & Rzamova, S. S. (2025). Empirical Investigation of the Re lationship Betwee n the Tourism Se ctor and Economic Growth: Case of Azerbaijan. *Problemy Ekonomiky*, (2), 10-15.
11. Huseynova, S., & Kazimov, J. (2025). Investment Incentives as a Tool for Sustainable Economic Development in the Azerbaijan Republic. *International Research Journal of Economics and Management Studies IRJEMS*, *4*(11).
12. Huseynova, S. M., & Gambarli, U. A. (2023). Cointegration and causality relationship of the USA stock market with selected world markets. *Бізнес Інформ*, (12), 128-134.
13. Huseynova, S., & Balajayeva, L. (2025). Digital Banking Regulation in Azerbaijan: Empirical Insights into User Trust, Risk Management, and Data Protection. *Journal of Eastern European and Central Asian Research (JEECAR)*, *12*(2), 80–97. https://doi.org/10.15549/jeecar.v12i2.2153
14. Hüseynova, S. Kapsayici Kalkinma Göstergelerinin Ekonomik Kalkinma Üzerindeki Etkisi. *Scientific Collection «InterConf+»*, (30), 28-31.
15. Huseynova S.M., Nwolisa N. Assessing the Impact of İnvestment and Oil Prices on the Trade Balance Between Azerbaijan and Russia Using Econometric Methods. *Statistics and Economics*. 2026;23(1):82-90. (In Russ.) https://doi.org/10.21686/2500-3925-2026-1-82-90
16. Andrejovská, A., & Glova, J. (2023). Economic Determinants Concerning Corporate Tax Revenue. Economies, 11(11), 268. https://doi.org/10.3390/economies11110268
17. Wang, Y., Lin, X., & Ni, H. (2025). Impact of Production Tax Policy on Water Resource and Economy: A Case Study of Wenling City. Sustainability, 17(18), 8117. https://doi.org/10.3390/su17188117
18. Fortea, C. (2025). Government Revenue Structure and Fiscal Performance in the G7: Evidence from a Panel Data Analysis. World, 6(3), 97. https://doi.org/10.3390/world6030097
19. Che, S., Kumar, R. R., & Stauvermann, P. J. (2021). Taxation of Land and Economic Growth. Economies, 9(2), 61. https://doi.org/10.3390/economies9020061
20. Panzaru, C., Belea, S., & Jianu, L. (2025). Delayed Taxation and Macroeconomic Stability: A Dynamic IS–LM Model with Memory Effects. Economies, 13(7), 208. https://doi.org/10.3390/economies13070208
21. Hira, A., Swartz, T., & Cao, J. (2026). Taxes, Growth, and Equity: The Illusions of Fiscal Policy. International Journal of Financial Studies, 14(2), 30. https://doi.org/10.3390/ijfs14020030
22. Bajrami, R., Bajraktari, K., & Gashi, A. (2025). The Impact of Economic Freedom on Economic Growth in Western Balkan Countries. Journal of Risk and Financial Management, 18(8), 461. https://doi.org/10.3390/jrfm18080461

23. Kaushik, P., Brahmi, M., Kakran, S., & Kansra, P. (2024). The Predictive Grey Forecasting Approach for Measuring Tax Collection. Journal of Risk and Financial Management, 17(12), 558. https://doi.org/10.3390/jrfm17120558

24. Quispe-Espinoza, E. P., Barzola-Inga, S. L., Adauto-Justo, C. A., Borja-Mucha, C. S., Moreno-Menéndez, F. M., Gutiérrez-Meza, F. P., Silva-Murillo, J. M., & González-Prida, V. (2025). Sustainable Economic Growth and Land Management: A Case Study on the Role of Tax Legislation in Emerging Markets. Land, 14(1), 30. https://doi.org/10.3390/land14010030

25. Rachidi, M., & El Moudden, A. (2025). Corporate Income Tax Differential and Subsidiaries' Profitability in Morocco: Profit-Shifting Evidence from a Pseudo-Ordinary Least Squares Framework. International Journal of Financial Studies, 13(4), 236. https://doi.org/10.3390/ijfs13040236

26. Файзиева Н.Р. (2021). НАЛОГООБЛОЖЕНИЕ И ЭКОНОМИЧЕСКИЙ РОСТ. Экономика и социум, (6-2 (85)), 414-417.

27. Чепикова Т. А. (2011). Налоговая политика и экономический рост. Царскосельские чтения, IV (XV), 98-104.

28. Журавлева Т.А. (2007). Налоговая составляющая экономического роста. Финансы и кредит, (13 (253)), 36-40.

29. Давыдова Л.В., & Фокина О.Г. (2004). Роль налогов в формировании стратегии экономического роста. Финансы и кредит, (28 (166)), 7-9.

30. Юзбашян А.П. (2023). НАЛОГОВАЯ СИСТЕМА РОССИИ И ЕЕ ВЛИЯНИЕ НА РАЗВИТИЕ ЭКОНОМИКИ. Вестник науки, 2 (6 (63)), 162-167.

31. Богачёв Сергей Валентинович, & Вишневский Валентин Павлович (2024). Налоговое стимулирование экономического роста в России: анализ с позиций налоговой динамичности. Terra Economicus, 22 (2), 22-38. Doi: 10.18522/2073-6606-2024-22-2-22-38

32. Маслова, Д. В. (2005). Налог на прибыль и стимулирование экономического роста. Известия высших учебных заведений. Северо-Кавказский регион. Общественные науки, (4), 64-67.

33. Какаулина М.О. (2014). Влияние налоговой нагрузки на экономический рост в Российской Федерации: региональный аспект. Региональная экономика: теория и практика, (17), 55-64.

34. Саламов Дж., & Мередова Г. (2024). РОЛЬ НАЛОГОВ В ЭКОНОМИЧЕСКОМ РАЗВИТИИ: АНАЛИЗ ВЗАИМОСВЯЗИ НАЛОГОВОЙ СИСТЕМЫ И ДОЛГОСРОЧНОГО РОСТА. Вестник науки, 3 (1 (70)), 114-117.

35. Анисимов, С. А. (2012). Модель влияния налоговой нагрузки на экономический рост. Финансовый журнал, (4), 65-74.

36. Вишневский Валентин Павлович, Матюшин Алексей Валериевич, & Стельмахова Наталья Валерьевна (2025). НАЛОГОВОЕ РЕГУЛИРОВАНИЕ ЭКОНОМИЧЕСКОГО РОСТА В УСЛОВИЯХ ПОСЛЕКРИЗИСНОГО ВОССТАНОВЛЕНИЯ: ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ. Проблемы прогнозирования, (1), 109-123. Doi: 10.47711/0868-6351-208-109-123

37. Новиков В.В., Таранцов М.А., & Шаховская Л.С. (2014). Универсальная формула налогообложения. Финансовая аналитика: проблемы и решения, (46), 45-55.

THE CURRENT STATE OF FINANCING EDUCATION THROUGH PUBLIC-PRIVATE PARTNERSHIP AND ISSUES OF ITS IMPROVEMENT

Uktamova N.
Researcher at Tashkent State University of Economics
ORCID: 0009-0004-0047-7543
DOI: 10.5281/zenodo.19827829

ABSTRACT

At present, ensuring the sustainable financing of the education sector, expanding its infrastructure, and improving the quality of educational services are issues of considerable relevance. In this process, public-private partnership serves as an important mechanism for attracting private capital to the education sector, creating new capacities, expanding coverage, and enhancing management efficiency. This approach is particularly significant in preschool education, where it helps reduce the burden on the state budget and improve the quality of educational services. Therefore, studying the current state of education financing based on public-private partnership and identifying directions for its further improvement is of substantial scientific importance.

Keywords: education, public-private partnership, social sphere, private investment, infrastructure, social effectiveness.

Introduction

Uzbekistan has made the sustainable financing of education, the development of educational infrastructure, and the improvement of access and quality indicators one of the priority areas of state policy. In particular, the expansion of the preschool education system and the enhancement of its effectiveness are regarded as essential conditions for improving the quality of human capital in the country. Preschool education lays a solid foundation for a child's future learning capacity, social adaptation, and intellectual development at subsequent stages of education. As President Shavkat Mirziyoyev has emphasized, "preschool education is a crucial stage in a child's intellectual, social, and spiritual development" [1]. This indicates that the development of this sector is important not only from a social perspective, but also in terms of its long-term economic significance.

The Decree of the President of the Republic of Uzbekistan No. PF-60 dated January 28, 2022, "On the Development Strategy of New Uzbekistan for 2022–2026," set the tasks of increasing preschool education coverage to at least 80 percent and ensuring full enrolment of six-year-old children in school preparation programs[2].

In this regard, President Shavkat Mirziyoyev, in one of his policy speeches, identified public-private partnership as a distinct practical mechanism. In particular, he emphasized that "another source for expanding preschool education coverage in remote areas is kindergartens established on the basis of public-private partnership"[3].

It was also stipulated that a three-year program would be developed for the construction of preschool institutions on the basis of public-private partnership in regions where preschool education coverage remains below 80 percent[4]. This suggests that public-private partnership in the education sector is no longer merely a separate initiative, but is gradually becoming a systematic instrument of development.

The study of the use of public-private partnership mechanisms in the education sector, particularly in preschool education, is currently regarded as one of the most relevant scientific issues from both theoretical and practical perspectives. These mechanisms create opportunities to expand the coverage of educational services, develop new capacities, attract private investment, optimize the burden on the state budget, and at the same time improve the quality of education. An analysis of the financing sources and social effectiveness of public-private partnership projects is therefore of significant scientific importance for the more efficient organization and sustainable development of the education sector.

In the academic literature, public-private partnership is primarily interpreted as a response to growing fiscal pressure in the social sphere and the increasing need for non-budgetary sources of financing. Matraeva et al. argue that PPPs have become especially relevant in such social sectors as healthcare, education, culture, and utilities, where public demand is high, while profitability remains low and project risks are relatively significant. According to the authors, the success of social-sector PPPs depends on well-designed incentives, public guarantees, and clear contractual arrangements that balance social goals and private-sector interests. In this regard, PPP is viewed not merely as an investment tool, but also as an institutional mechanism for sustaining socially important services under budget constraints[5].

Within the education sector, the literature emphasizes the role of PPPs in diversifying financing sources

[1] Further improvements to the preschool education system discussed // https://gov.uz/en/news/view/128095

[2] Decree of the President of the Republic of Uzbekistan No. PF-60, dated January 28, 2022, "On the Development Strategy of New Uzbekistan for 2022–2026" // National Database of Legislation, Lex.uz.

[3] Issues on Expansion of Pre-school Education Discussed // https://president.uz/en/lists/view/4380

[4] Priority tasks set in the sphere of pre-school and school education // https://president.uz/en/lists/view/8471

[5] Matraeva, Liliia V., Alexey A. Konov, Alexey V. Belyak, Sergey G. Erokhin, and Ekaterina S. Vasyutina. "Public Private Partnership in Social Sphere: Models Review." International Journal of Economics and Financial Issues 6, Special Issue (S8) (2016): 127–136.

and introducing more result-oriented funding arrangements. Kim and Han maintain that PPP-based education financing, particularly through social impact bond structures, can help reduce budgetary capital constraints while incorporating performance-based principles into educational projects. Their study shows that such models differ from traditional public financing because they rely on predefined success metrics, risk-sharing arrangements, and external evaluation, thereby strengthening transparency and accountability in education funding. This perspective is particularly important for countries seeking to expand educational access without relying exclusively on state resources[6].

Recent research also presents PPP as a broader instrument of educational transformation. Ahmad and Alam note that PPPs can contribute not only to infrastructure development, but also to teacher training, curriculum modernization, technology integration, and improved access for underserved groups. Their review demonstrates that PPP models such as Build-Operate-Transfer, management contracts, voucher schemes, and adopt-a-school programs can improve both educational coverage and service quality. At the same time, the authors underline that the effectiveness of PPPs depends on policy coherence, accountability mechanisms, financial sustainability, and stakeholder coordination. This suggests that PPPs in education should be assessed not solely in financial terms, but also through their institutional and social impact[7].

In the Uzbek scholarly context, Nasurova emphasizes the importance of PPPs in financing preschool educational organizations. Her study highlights that PPP mechanisms may support the attraction of private investment, the modernization of infrastructure, the strengthening of staff capacity, and the improvement of education quality. She also argues that PPPs may increase the sustainability of the preschool education system by combining public resources with private-sector financial and managerial experience. At the same time, her work indicates that the practical effectiveness of PPPs in preschool education depends on adapting international experience to national conditions and improving financing mechanisms in line with domestic legal and institutional frameworks[8].

Taken together, the reviewed studies show that public-private partnership in education should be understood as a multidimensional mechanism. On the one hand, it serves as a source of additional financing and a means of infrastructure development. On the other hand, it influences educational quality, access, innovation, and institutional sustainability. Therefore, the study of the current state of education financing through public-private partnership, as well as the identification of directions for its improvement, is of considerable scientific and practical importance.

Methodology

In this study, systemic and comparative analysis methods were employed to examine the use of public-private partnership mechanisms in the education sector and the practice of their financing. Through a systemic approach, public-private partnership was assessed as an integrated economic mechanism associated with the financing of education, the development of infrastructure, and the expansion of service coverage.

For the statistical analysis, tabular data on public-private partnership projects implemented in 2020–2025 were used as the empirical basis. On this basis, the number and value of projects, their sectoral distribution, the composition of the social sphere, and the position of the education sector within the overall indicators were identified.

Results

At this stage of the study, trends in the sectoral changes in the number of public-private partnership projects during 2020–2024 were examined. The results of the analysis indicate that the number of projects increased steadily in the economic and social sectors, whereas the growth rate in other sectors was relatively lower.

Table 1.

Value of PPP Projects Implemented by Sector in 2020–2025 (mln UZS)[9]

Indicators	2020	2021	2022	2023	2024	2025	Total
Economics	43 453,3	169 762,8	17 915 399,7	446 746,5	328 101 553,9	1 036 391,7	347 713 308,0
Social	149 911,9	400 108,1	1 110 579,6	2 262 883,4	1 513 114,1	2 146 430,0	7 583 027,0
Other spheres	106 110,2	539 560,1	713 757,8	426 971,6	18 852,0	-	1 805 251,8
Total	**299 475,5**	**1 109 431,1**	**19 739 737,1**	**3 136 601,5**	**329 633 520,0**	**3 182 821,6**	**357 101 586,8**

The sectoral analysis of public-private partnership projects implemented in 2020–2025 shows that the scope of this mechanism in the economy and social sphere of Uzbekistan has expanded significantly over the years. According to the indicators presented in Table 1, a total of 2,982 public-private partnership projects were implemented during the period under review, with a total value of UZS 357.1 trillion. These figures

[6] Kim, Jasper, and Michelle Han. "Education Financing and Public-Private Partnership Development Assistance Model." Procedia - Social and Behavioral Sciences 177 (2015): 100–103.

[7] Ahmad, Fakhruddin Ali, and Aftab Alam. "Role of Public-Private Partnerships in Transforming Education." International Journal for Innovative Research in Multidisciplinary Field 11, no. 2 (2025): 186–193.

[8] Nasurova K.R. "The Importance of Public-Private Partnership in Financing Preschool Educational Organizations." International Finance & Accounting 5 (2024).

[9] **Source:** Compiled by the author based on data from the official website of the Ministry of Economy and Finance.

confirm that public-private partnership is emerging as an important investment and organizational instrument in the country.

In sectoral terms, the largest share of public-private partnership projects was concentrated in the economic sectors. In particular, a total of 2,138 projects were implemented in the economic sphere in 2020–2025, with a total value of UZS 347.7 trillion. This means that the economic sectors accounted for 71.7 percent of the total number of projects and 97.4 percent of their total value. This indicates that public-private partnership has been applied more actively in economic sectors characterized by high capital intensity and a need for large-scale investment.

In the social sphere, 764 projects were implemented, with a total value of UZS 7.6 trillion. Although this represents 25.6 percent of the total number of projects, its share in total value amounts to only 2.1 percent. This suggests that while the number of public-private partnership projects in the social sphere may be relatively high, their average value remains considerably lower than that of large infrastructure projects in the economic sectors. Other sectors accounted for only 80 projects with a total value of UZS 1.8 trillion, indicating their relatively limited share.

In particular, while a total of 51 projects worth UZS 299,475.5 million were implemented in 2020, by 2025 the number of projects had increased to 1,758. This indicates a sharp rise in the number of public-private partnership projects. However, in value terms, the highest figure was recorded in 2024, when the total amount reached UZS 329,633,520.0 million. This means that nearly 92.3 percent of the total value accumulated over the six-year period under analysis was concentrated in 2024. The sharp increase in the value of public-private partnership projects in 2024 can be explained by the Decree of the President of the Republic of Uzbekistan No. PF-158 dated September 11, 2023, "On the Strategy 'Uzbekistan – 2030.'"

This document set the tasks of developing and implementing large-scale investment projects within the framework of public-private partnership, expanding private sector participation in priority sectors, and attracting USD 30 billion in PPP investments by 2030.

Although the number of projects reached its highest level in 2025, their total value was considerably lower than in 2024. This suggests that, alongside large capital-intensive projects, the practice of public-private partnership has increasingly expanded to include numerous relatively small- and medium-sized projects as well.

Table 2

Value of PPP Projects Implemented in the Social Sphere in 2020–2025 (mln UZS)[10]

Indicators	2020	2021	2022	2023	2024	2025	Total
Employment	-	-	778,0	-	920,0	-	1 698,0
Social sphere	6 000,0	-	-	1 453 736,4	-	3 712,9	1 463 449,3
Culture	-	34 648,5	69 356,3	68 160,0	102 171,9	261 284,0	535 620,7
Healthcare	51 852,0	319 406,8	138 476,0	95 533,9	34 418,8	380 301,8	1 019 989,2
Sports	-	-	-	24 899,5	19 909,0	89 911,6	134 720,1
Education	92 059,9	46 052,9	901 969,3	620 553,6	1 355 694,4	1 411 219,6	4 427 549,7
Total	**149 911,9**	**400 108,1**	**1 110 579,6**	**2 262 883,4**	**1 513 114,1**	**2 146 430,0**	**7 583 027,0**

According to the indicators presented in Table 2, out of the 764 projects implemented in the social sphere during 2020–2025, 324 were in the education sector. This accounts for 42.4 percent of the total number of projects in the social sphere. In value terms, the total volume of projects implemented in the education sector amounted to UZS 4,427,549.7 million, which is equivalent to 58.4 percent of the total value of the social sphere. These figures indicate that the education sector has become the most priority segment of public-private partnership within the social sphere.

The year-by-year dynamics of public-private partnership projects in the education sector also demonstrate a consistent upward trend. In particular, while 24 projects were implemented in the education sector in 2020, this figure had increased to 174 by 2025. Over this period, the number of projects in the education sector grew by 7.25 times. In value terms, growth was observed from UZS 92,059.9 million in 2020 to UZS 1,411,219.6 million in 2025, which means that this indicator increased by nearly 15.3 times. This suggests that private investment and partnership mechanisms have been entering the education sector with increasing intensity.

An examination of the internal structure of the social sphere shows that sectoral priorities changed in some years. In 2020, the education sector took the lead, accounting for 66.7 percent of the total number of projects in the social sphere and 61.4 percent of their total value. In 2021, however, the healthcare sector moved into the leading position with 17 projects valued at UZS 319,406.8 million. In 2022, the education sector regained its dominance, accounting for 81.2 percent of the total value in the social sphere. In 2023, the structure differed somewhat, as 219 projects were recorded under the generalized category of the "social sphere." Nevertheless, in 2024 and 2025 the education sector once again held the highest share, with 59 and 174 projects respectively, emerging as the main driver within the social sphere.

Based on the above analysis, the education sector can be considered the most active and the largest-value segment of public-private partnership projects in the social sphere. However, when viewed across all sectors, the share of education projects accounts for only

[10] **Source:** Compiled by the author based on data from the official website of the Ministry of Economy and Finance.

about 10.9 percent of the total number of projects and merely 1.24 percent of their overall value. This makes it possible to draw two important conclusions.

First, the public-private partnership mechanism has been actively introduced into practice in the education sector and has become a priority area within the social sphere.

Second, from the perspective of the overall scale of investment, the education sector has not yet reached a level comparable to the large public-private partnership projects implemented in the economic sectors. Therefore, the further development of public-private partnership in education requires not only an increase in the number of projects, but also strengthening their financial scale, quality, and long-term social effectiveness.

From this perspective, the indicators presented in the tables demonstrate that there is substantial demand and significant potential for the further development of public-private partnership in the education sector. In particular, this mechanism may serve as an important economic instrument for expanding preschool and general secondary education infrastructure, creating new places, improving the quality of educational services, and attracting private capital more effectively. Therefore, in promoting public-private partnership in education, it is necessary to take into account not only its quantitative dimensions, but also its quality, efficiency, and regional balance.

Public-private partnership in the education sector is emerging not merely as a means of attracting additional funding, but also as an important institutional mechanism that contributes to infrastructure expansion, the creation of new capacities, and the increased accessibility of educational services for the population.

The effectiveness of public-private partnership mechanisms in education should be assessed not only by the number of projects or the volume of funds attracted, but also by their social outcomes. In particular, these mechanisms create opportunities to expand preschool education coverage, reduce disparities between regions, improve the quality of education, and introduce new pedagogical and managerial approaches. From this standpoint, the evaluation of public-private partnership should be based not only on financial indicators, but also on such criteria as coverage, quality, regional balance, utilization rates, and social effectiveness.

For public-private partnership to function successfully in the education sector, the mere availability of financial resources is not sufficient. Equally important are the effective implementation of the legal framework, the clear allocation of responsibilities between the public and private partners, an efficient monitoring system, appropriate state support measures, and the proper consideration of regional needs. Otherwise, despite an increase in the number of projects, their social effectiveness may fail to reach the expected level.

Conclusion

In conclusion, public-private partnership mechanisms in Uzbekistan's education sector, particularly in preschool education, have entered an important stage of development. These mechanisms create opportunities to expand the coverage of educational services, attract private investment, and partially reduce the burden on the state budget. However, in the next stage, the main focus should not be placed merely on increasing the number of projects, but rather on ensuring their quality, institutional sustainability, and social effectiveness. Only under these conditions can public-private partnership become an effective instrument for the sustainable financing of education and for enhancing its competitiveness.

References

1. President of the Republic of Uzbekistan. "Issues on Expansion of Pre-School Education Discussed." Accessed via https://president.uz/en/lists/view/4380

2. President of the Republic of Uzbekistan. "Priority Tasks Set in the Sphere of Pre-School and School Education." Accessed via https://president.uz/en/lists/view/8471.

3. Government Portal of the Republic of Uzbekistan. "Further Improvements to the Preschool Education System Discussed." Accessed via https://gov.uz/en/news/view/128095

4. President of the Republic of Uzbekistan, Decree No. PF-158 of September 11, 2023, "On the Strategy "Uzbekistan–2030",'" National Database of Legislation (Lex.uz) // https://lex.uz/ru/docs/-6600413.

5. Matraeva, Liliia V., Alexey A. Konov, Alexey V. Belyak, Sergey G. Erokhin, and Ekaterina S. Vasyutina. "Public Private Partnership in Social Sphere: Models Review." International Journal of Economics and Financial Issues 6, Special Issue (S8) (2016): 127–136.

6. Kim, Jasper, and Michelle Han. "Education Financing and Public-Private Partnership Development Assistance Model." Procedia – Social and Behavioral Sciences 177 (2015): 100–103.

7. Ahmad, Fakhruddin Ali, and Aftab Alam. "Role of Public-Private Partnerships in Transforming Education." International Journal for Innovative Research in Multidisciplinary Field 11, no. 2 (2025): 186–193.

8. Nasurova K.R. "The Importance of Public-Private Partnership in Financing Preschool Educational Organizations." International Finance & Accounting 5 (2024).

HISTORICAL SCIENCES

POLITICAL AND MILITARY ACTIVITIES OF THE KHWARAZMSHAHS IN AZERBAIJAN

Aliyev I.
Phd. In History
Nakhchivan Branch of ANAS
ORCİD İD: 0000-0002-7079-4737
Aliyeva K.
Nakhchivan Branch of ANAS
ORCİD İD: 0009-0005-7620-3255
DOI: 10.5281/zenodo.19827843

ABSTRACT

This article examines the political and military activities of the Khwarazmshahs in Azerbaijan during the late twelfth and early thirteenth centuries, with particular emphasis on the campaigns and governance of Jalal al-Din Khwarazmshah. The study employs a historical-critical and contextual methodology based on primary medieval sources and relevant regional scholarship. Political and military developments are analyzed alongside administrative practices and their socio-economic impact on the local population.

The article situates Khwarazmshah expansion within the broader context of Seljuk fragmentation, regional feudal rivalry, and the Mongol threat, highlighting Azerbaijan's strategic significance during this transitional period. Special attention is given to key regions such as Tabriz and Nakhchivan, where Jalal al-Din attempted to establish a new political center following the collapse of Khwarazmshah authority in Central Asia.

The findings demonstrate that although Jalal al-Din's rule in Azerbaijan was short-lived, his military campaigns and administrative policies significantly affected the region's political stability and social structure, contributing to the conditions that facilitated subsequent Mongol domination. By adopting a region-centered perspective, this study offers a reassessment of Khwarazmshah rule in Azerbaijan and contributes to the historiography of medieval Caucasia on the eve of the Mongol invasions.

Keywords: Khwarazmshah Jalal al-Din, 13th century Azerbaijani history, Mongol invasions, Nakhchivan campaign, Feudal power, strategic position.

INTRODUCTİON.

In the early thirteenth century (1200-1220), the Middle East and the South Caucasus were under the influence of complex political processes. As a result of the disintegration of the Great Seljuk Empire (1038-1157), which had held a dominant position in the region from the late eleventh to the mid-twelfth century, central authority weakened and political fragmentation emerged among local feudal states and dynasties. This situation rendered the Caucasus and the lands of Azerbaijan increasingly vulnerable to the influence and interventions of external powers. At that time, political authority in Azerbaijan was exercised by several states, including the Eldiguzid state (the Atabegs of Azerbaijan, 1146-1225), the Shirvanshah state (861-1538), and the Aghsunqurids of Maragha (1122-1227). By the late twelfth century, the increasingly powerful Georgian Kingdom, along with the Khwarazmian Empire, which sought to maintain its influence in the region, emerged as the principal rival forces contending for control over Azerbaijan. During the late twelfth and early thirteenth centuries, military campaigns by the Georgians, Mongols, and Khwarazmians were launched against Azerbaijan. The absence of a unified state structure and strong local authority in Azerbaijan contributed to the increased frequency and destructive impact of these invasions.

RELATİONS BETWEEN THE ATABEGS OF AZERBAİJAN AND THE KHWARAZMİANS.

During the reign of Atabeg Shams al-Din Eldiguz, relations between the Atabegs of Azerbaijan and the Khwarazmians were marked by tension. Following the death of Sultan Sanjar (1117-1157) in 1157, Il-Arslan Khwarazmshah (1156-1172) launched a campaign to seize Nishapur and placed the region under siege. The ruler of Nishapur, Muʾayyid Ay-Aba, relied on Arslan Shah for assistance, particularly on Shams al-Din Eldiguz. In an effort to halt the Khwarazmshah's advance, Shams al-Din Eldiguz marched from Hamadan to Rayy and then to Bistam. However, the battle fought between the two sides ended without a decisive outcome. As a result of Muʾayyid Ay-Aba's submission to Khwarazmshah authority, Nishapur was ultimately lost (3, p. 68; 12, p.534).

Hostile relations with the Khwarazmians during the time of Shams al-Din Eldiguz were transformed into amicable ties under Atabeg Muhammad Jahan Pahlavan (1175-1186). The correspondence exchanged between Muhammad Jahan Pahlavan and Ala al-Din Tekish (1172-1200) was conducted in a spirit of friendship. In the first, second, and fourth letters, the parties discussed the establishment of diplomatic missions, the Khwarazmshah's desire to meet in person, and the exchange of gifts. In the third letter, however, they complained about the great distance between their realms and the resulting difficulty in maintaining frequent correspondence (3, p.78; 10, p.109).

Following the death of Qizil Arslan (1186-1191), the internal struggle for power within the Atabegs of Azerbaijan was exploited by Tughril III, who, after being released from captivity, seized control of Iraqi Iran. In his struggle against Tughril III, Qutluq Inanch sought assistance from Khwarazmshah Tekish. At the same time, the Abbasid caliph al-Nasir also wrote to Khwarazmshah Tekish, inviting him to the region to oppose Tughril III. After Tughril III was defeated, Hamadan and Iraqi Iran came under Khwarazmian rule. Shortly thereafter, Khwarazmshah Tekish sent a letter to Abu Bakr (1191-1210), proposing to grant him authority over Iraq and inviting him to a meeting. However, taking into account the Georgian incursions, Abu Bakr sent his brother Uzbek (1210-1225) to meet the Khwarazmshah instead (3, p.110). In 602 AH (1205-1206), Taj al-Din Ali Shah, the son of the Khwarazmshah, launched an attack on the territory of the Atabegs of Azerbaijan. in the ensuing battle, Abu Bakr emerged victorious and destroyed the fortress of Haydariyya (3, p.118). Thus, the friendly relations that had begun during the reign of Muhammad Jahan Pahlavan eventually gave way to hostility.

In the thirteenth century, the Mongol state strengthened in Central Asia, prompting the Khwarazmians to advance westward. The Khwarazmian attacks on the Eldiguzid state further exacerbated the situation. Initially, the attack was led by Ghiyath al-Din Pirshah, the son of Khwarazmshah Muhammad (1200-1220). In order to avert this campaign, Uzbek married his sister Jalaliyya to Pirshah (15, p.99). After Ghiyath al-Din Pirshah withdrew from Azerbaijan, Uzbek attempted to take advantage of the temporary stabilization by launching an against Iraq. Simultaneously, the Atabeg of Fars, Saʿd ibn Zangi (1194-1226), also advanced into Iraq. Upon learning of these attacks, Khwarazmshah Muhammad initiated a campaign and, within a short period, defeated Saʿd ibn Zangi and took him captive. Khwarazmshah Muhammad then dispatched his vizier, Nasr al-Din Dawlatyar, to Uzbek, demanding his submission. Realizing that he lacked the strength to resist the Khwarazmshah, Uzbek ordered the khutba to be read in his name. Since Uzbek's principal fortresses and treasury fell into Khwarazmian hands, no tribute was demanded. During these years, the Georgians were once again preparing to launch a campaign against Azerbaijan. Atabeg Uzbek appealed to the Khwarazmshah for assistance, and as a result, the Georgian expedition did not materialize (11, p.30; 9, p. 366; 12, p.549).

The Khwarazmian state reached its greatest territorial extent during the reign of Ala al-Din Muhammad (1200-1220), transforming into a major political power stretching from the Caspian Sea to the Indian Ocean. However, this period was also marked by severe crises in the internal administration of the state. The tension that began with the killing of Mongol envoys in 1218 ultimately drew the Khwarazmians into open warfare with the Mongols. Between 1219 and 1221, the armies of Chinggis Khan inflicted devastating blows on the Khwarazmian state, bringing it to the brink of collapse. As a result, the main pillars of the state were destroyed, the capital Urgench and other major cities were devastated, and the foundations of political authority were severely undermined. The political vacuum created by the Mongol invasions (1219-1223) had particularly significant consequences for Azerbaijan. In the early 1220s, the commanders of Chinggis Khan advanced into the South Caucasus, entering the regions of Shirvan, Arran, and Nakhchivan. These campaigns further heightened Mongol interest in Azerbaijan due to its strategic and geographical position-situated at the crossroads of major trade routes and endowed with rich economic resources. In 1221, Mongol forces conducted military operations in the directions of Nakhchivan, Ganja, and Tbilisi, seeking to establish control over the region (2, p.163; 15, p. 99; 4, p. 38;6, p. 92). Consequently, in the

early thirteenth century, the lands of Azerbaijan became a major arena of the Khwarazmian-Mongol confrontation.

KHWARAZMSHAH JALAL AL-DİN'S CAMPAİGNS İN AZERBAİJAN.

In 1220, Ala al-Din Muhammad, ruler of the Khwarazmian state, died on the island of Abaskun in the Caspian Sea (located in present-day Gorgan, Iran). Following his death, the state found itself in a grave military and political crisis, as the Mongol armies of Chinggis Khan had devastated Khwarazmian territories through successive campaigns between 1219 and 1221. Shortly before his death, Khwarazmshah Muhammad had designated his son Jalal al-Din as his heir (12, p. 641; 7, p. 400). Unlike his father's weakened authority, Jalal al-Din sought to consolidate the remaining forces of the state and organize resistance against the Mongol invasion.

In the early years of his rule, Khwarazmshah Jalal al-Din waged a determined struggle against the Mongols. In November 1221, he inflicted a significant defeat on Chinggis Khan's forces at the Battle of Parwan around the Indus River. However, later in 1221, as a result of renewed and powerful Mongol offensives, he suffered defeat and was forced to retreat to India. In 1224, Jalal al-Din returned from India and launched a new campaign toward the lands of Iran and Azerbaijan (14, p. 249). His principal objective was to organize sustained resistance against the Mongols and to revive his state.

Jalal al-Din's plans concerning the Caucasus and Azerbaijan were of a strategic nature. In 1225, he entered Azerbaijan and captured Tabriz; in 1226, he launched a campaign against Georgia and seized Tbilisi, attempting to consolidate his position in the region. Nakhchivan and its surrounding areas were of particular importance to him, as the region was advantageous from a defensive standpoint and represented a strategic base for resistance against the Mongols. Between 1225 and 1230, Jalal al-Din sought to transform Azerbaijan into one of the main pillars of his rule while simultaneously confronting the Mongol threat and engaging in struggles with local feudal powers. After 1221, as a result of continuous Mongol attacks, Khwarazmshah Jalal al-Din was deprived of the principal centers of his state and, upon returning from India in 1224, began searching for a new base of consolidation. Since the Mongol danger remained acute, he was compelled to select a strategically advantageous territory in order to preserve his political and military position. Azerbaijan proved to be the most suitable region for this purpose, as the Mongol campaigns of 1220-1222 had disrupted political stability and deepened fragmentation among local feudal elites (14, p.99; 16, p. 49). In such circumstances, Jalal al-Din entered Azerbaijan with the aim of establishing a new center of authority and securing a base for resistance against the Mongols.

The economic and military significance of Azerbaijan was also one of the principal reasons behind the campaign. Cities such as Tabriz, Ganja, and Nakhchivan-located along major international trade routes running from north to south and from east to west-possessed substantial financial resources as well as strategically important military positions. When Jalal al-Din launched his campaign into Azerbaijan in 1225, one of his primary objectives was to bring these cities under his control. At the same time, another crucial strategic goal was to establish alliances among local feudal lords against the Mongol threat and to subordinate their military forces to his authority. In mid-1225, Jalal al-Din entered Tabriz with his army and from there directed his forces toward Nakhchivan. In Nakhchivan, the Khwarazmshah's army encountered various military and political actors. At that time, the administration of Nakhchivan was in the hands of Khatun Jalaliyya. First and foremost, local feudal rulers in the region sought to preserve their own positions and therefore approached Jalal al-Din's campaign with caution. Moreover, the continued Mongol threat, along with the territorial ambitions of the Georgian kingdom in the Caucasus, further complicated Jalal al-Din's military operations. As a result of the campaigns conducted around Nakhchivan in 1225-1226, the Khwarazmshah army temporarily established control over the region. The attitude of the local population played a significant role in shaping the course of these campaigns.

Due to its strategic location, economic potential, and proximity to major trade routes, Nakhchivan constituted an important stronghold for the Khwarazmians. In administering the territory, Jalal al-Din applied classical military-feudal methods. The presence of the Khwarazmshah army in Nakhchivan led to increased control of local administration by foreign military forces. In 1226-1227, heavy taxes were imposed in the region, and food supplies and livestock were requisitioned to meet the needs of the army. This policy placed a considerable economic and social burden on the local population. In shaʿban 624 AH (july-august 1227), Hajib Ali led a campaign into Azerbaijan and captured the city of Khoy. According to al-Nasawi, after taking Khoy, its surrounding fortresses, and Marand, he advanced toward Nakhchivan, which surrendered to him without resistance (11, p. 270; 1, p. 56). Ibn al-Athir likewise reports that the inhabitants of Nakhchivan voluntarily surrendered the city to Hajib Husam al-Din Ali, noting that had he wished to continue, he could have conquered the entire country (8, p. 199; 5, p. 55-56). Initially perceived as a defensive force against the Mongols, Jalal al-Din's system of governance soon generated widespread dissatisfaction. The voluntary surrender of Nakhchivan's population to Hajib Ali clearly demonstrates the local population's discontent with the harsh policies of the Khwarazmians.

In the final years of his rule, a certain moderation can be observed in Jalal al-Din Khwarazmshah's policies. Prolonged warfare had reduced the population to impoverishment. Taking into account the dire conditions of the population around Tabriz, Jalal al-Din ordered the distribution of food supplies from state granaries. In addition, the inhabitants of Tabriz were exempted from taxation for a period of three years (6, p. 95).

Nevertheless, the persistence of the Mongol threat and the growing dissatisfaction among the local population weakened Jalal al-Din's position. From 1229-

1230 onward, Mongol forces under the command of Chormaqan Noyan launched a campaign from Turkestan. Unlike earlier incursions, the primary objective of these Mongol campaigns was to establish firm control over the Caucasus and Asia Minor. Jalal al-Din called upon local rulers to unite against the Mongols; however, due to his harsh policies, regional authorities failed to form a united front.

After 1227, Jalal al-Din undertook a series of measures to consolidate his authority in Azerbaijan. His principal aim was to bring the regions of Tabriz, Nakhchivan, and Arran fully under his control. However, continued Mongol pressure prevented the realization of these plans. Renewed Mongol incursions into the South Caucasus in 1228-1229 weakened Jalal al-Din's forces and forced him into a defensive posture. Consequently, his authority in Azerbaijan remained partial and temporary. At the same time, the dual policies pursued by local feudal elites posed a serious obstacle to the stability of Khwarazmshah rule. While some feudal lords regarded Jalal al-Din as a bulwark against the Mongol threat, others grew increasingly dissatisfied with his heavy taxation and military demands. As a result of these tensions, by 1229-1230 Jalal al-Din had lost both domestic support and key military foundations.

In 1230, his defeat by the army of the Anatolian Seljuk sultan Ala al-Din Kayqubad I at the Battle of Yassıçemen brought an end to his position in Azerbaijan. Jalal al-Din's attempts to establish a lasting base of power in the region ultimately failed. Following his defeat, he was killed in one of the mountain villages near Amid where he had sought refuge (13, p. 230). Thus, with the death of Jalal al-Din Khwarazmshah, the Khwarazmian dynasty disappeared from the stage of history.

CONCLUSİON.

The campaigns of Jalal al-Din Khwarazmshah in Azerbaijan between 1225 and 1230 had a significant impact on the country's political life. As a result of his activities, temporary Khwarazmian rule was established in Tabriz, Nakhchivan, and other regions. Although this authority created a certain degree of resistance against the Mongols, lasting stability could not be achieved due to internal contradictions and feudal fragmentation. Jalal al-Din's defeat at the Battle of Yassıçemen in 1230 marked the end of his political career and eliminated his influence in Azerbaijan. With his death in 1231, the remaining structures of the Khwarazmian state also collapsed. These campaigns are regarded as a significant stage in the history of Azerbaijan. Although Jalal al-Din's rule was short-lived, it paved the way for the acceleration of Mongol invasions in the subsequent decades of the thirteenth century (1231-1240). The heavy taxation and military policies imposed by the Khwarazmians in the region severely worsened the socio-economic conditions of the local population and greatly undermined the capacity for resistance against the Mongols. As a result, from the late 1230s onward, Azerbaijan came under Mongol political control. Thus, Jalal al-Din's campaigns constituted a crucial transitional period in Azerbaijani history on the eve of the Mongol conquest and played a decisive role in shaping the country's political fate.

The analysis demonstrates that during the period when the Eldiguzid (Atabeg) state of Azerbaijan was politically and militarily strong-particularly under the rule of Muhammad Jahan Pahlavan and Qizil Arslan-relations with the Khwarazmshah state were largely characterized by cooperation and peaceful interaction. However, as the Eldiguzid state weakened, Khwarazmshah military incursions into the region intensified, and tendencies toward vassal dependency became increasingly evident. The campaigns of Khwarazmshah Jalal al-Din in Azerbaijan, accompanied by harsh political measures, further aggravated the socio-economic conditions of the population and left the region vulnerable to external threats. Moreover, the lack of trust displayed by the local population and regional elites toward Khwarazmshah authority, as well as their appeal to Hajib Ali for assistance, clearly illustrates the nature and consequences of these political developments.

References

1. Aliyev, İ., & Aliyeva, K. (2025). The Khwarazmshah dynasty's military expeditions into the Nakhchivan region during the 1220s. *Norwegian Journal of Development of the International Science*, 53–56.

2. Bunyadov, Z. M. (2015). *A history of the Khorezmian state under the Anushteginids (1097–1231).* Samarkand.

3. Bünyadov, Z. M. (2007). *Azərbaycan Atabəyləri dövləti (1136–1225-ci illər).* Bakı: Şərq-Qərb.

4. Əliyev, İ. (2024). Monqolların Naxçıvana hücumları və onun nəticələri. In *Şərqin Qapısı – Qədim diyar* (pp. 37–52). Naxçıvan: Əcəmi.

5. Əliyeva, K. (2024). Naxçıvan bölgəsi gürcülərin Azərbaycana yürüşləri zamanında (XII–XIII əsrin 20-ci illəri). *Azərbaycan Milli Elmlər Akademiyası Naxçıvan Bölməsinin Elmi əsərləri*, 52–58.

6. Geyiklioğlu, H. (1996). Harezmşah Celaleddin Mengüberti'nin şahsiyeti. *Atatürk Üniversitesi Türkiyat Araştırmaları Dergisi*, (14), 89–102.

7. Huseynov, G. (2024). Celaleddin Harizmşah'ın Azerbaycan'ı istilası ve Atabeyler devleti'nin çöküşü. *Genel Türk Tarihi Araştırmaları Dergisi*, *6*, 397–410.

8. İbn əl-Əsir. (1959). *Əl-Kamil fi-t-tarix* (M. Əfəndizadə, Trans.). Bakı: Azərbaycan SSR Elmlər Akademiyası nəşriyyatı. (Original work published ca. 1231).

9. Juzjani, M. (1881). *Tabakat-i-Nasiri* (M. H. G. Raverty, Trans., Vol. 1). London: Gilbert & Rivington.

10. Kafesoğlu, İ. (2000). *Harezmşahlar devleti tarihi.* Ankara: Türk Tarih Kurumu.

11. Nasawi, M. (1895). *Historie du Sultan Djelal ed-din Mankobirti (prince du Kharezm)* (O. Houdas, Trans.). Paris.

12. Nəcəf, Ə. (2010). *Səlcuqlu dövlətləri və Atabəyləri tarixi.* Bakı: Qanun.

13. Taneri, A. (1993). Celaleddin Harezmşah. In *Türkiye Diyanet Vakfı İslam Ansiklopedisi* (Vol. 7, pp. 248–250). Ankara.

14. Taneri, A. (1998). Harezmşahlar. In *Türkiye Diyanet Vakfı İslam Ansiklopedisi* (Vol. 16, pp. 228–231). Ankara.

15. Vəlixanlı, N. (2016). *Azərbaycan VII–XII əsrlərdə: tarix, mənbələr, şərhlər.* Bakı: Elm və təhsil.

16. Yınanç, H. (1977). Celaleddin Harezmşah. In *İslam Ansiklopedisi* (Vol. 3, pp. 49–53). İstanbul: Milli Eğitim Basımevi.

MEDICAL SCIENCES

EXPERIMENTAL STUDY OF ULTRASTRUCTURAL CHANGES IN THE ORAL MUCOSA OF RATS AFTER FIREARM AND NON-FIREARM INJURIES TO THE MAXILLOFACIAL REGION

Logai V.
Candidate of Medical Sciences
Associate Professor
Department of Traumatology, Orthopedics and Military-Field Surgery
Odessa National Medical University
Odesa, Ukraine
ORCID: 0009-0007-9977-5162
DOI: 10.5281/zenodo.19827893

ABSTRACT

Gunshot wounds are among the most severe forms of traumatic injury, characterized by a complex clinical course, a high rate of complications, and substantial disability in affected individuals. Against the backdrop of ongoing armed conflicts, widespread access to firearms, and an increasing number of terrorist attacks, the frequency of such injuries continues to grow, placing the issues of their diagnosis and treatment at the forefront of contemporary clinical practice.

Although a considerable body of research has been dedicated to gunshot injuries, numerous aspects of their pathogenesis, tissue morphological changes, and the recovery of maxillofacial structures remain poorly understood. This highlights the need for continued experimental and clinical investigation aimed at gaining a deeper insight into the mechanisms of tissue damage, as well as at developing more effective approaches to surgical correction and patient rehabilitation.

To study the ultrastructural changes in the skin and oral mucosa the following **tasks** were set:

1. To study the ultrastructural changes in the skin and oral mucosa after gunshot-induced jaw injury in an in vivo experimental rat model.
2. To study the ultrastructural changes in the skin and oral mucosa after gunshot-induced jaw injury in an in vivo experimental rat model.

Materials and Methods

The study was conducted on seven adult Wistar rats, divided into three groups: Group I — control (intact animal); Group II — experimental group with mechanically induced injury; Group III — experimental group with firearm-induced injury.

For electron microscopic examination, fragments of bone and soft tissue from the rat jaws were fixed in a 2.5% glutaraldehyde solution prepared in phosphate buffer at pH 7.4, followed by post-fixation in a 1% osmium tetroxide solution in the same buffer. The samples were then dehydrated in a graded series of ethanol. Impregnation and embedding of the material were performed in a mixture of Epon–Araldite epoxy resins. Subsequently, ultrathin sections were contrasted according to the Reynolds method.

Results of the Study

It was established that, following a gunshot injury, the examined tissues exhibited more pronounced manifestations of productive inflammation than after a mechanical fracture. The gunshot wound affected wider areas with destructive and necrotic changes in the soft tissues of the rats compared to mechanical trauma. These alterations were characterized by an accumulation of numerous histiogenic cells, primarily macrophages and mast cells. Moreover, some mast cell granules showed signs of histamine release, suggesting a reaction to an allergic component, possibly to gunpowder residues in this experimental setting.

Additionally, after the gunshot injury, the tissues experienced extensive and severe damage, including destruction and necrosis of both connective tissue cells and collagen fibers. At the same time, the affected area demonstrated an increased number of fibroblasts actively engaged in protein synthesis directed toward collagen production and the formation of collagen fibrils compared with mechanical fracture.

On the 7th day after the gunshot injury, the soft tissues of the rats showed productive inflammation in the proliferative phase, accompanied by elements of reparative regeneration. By contrast, on the 7th day after a mechanical fracture, the intensity of productive inflammation in the soft tissues was significantly lower than that observed after the gunshot wound.

Keywords: gunshot wounds, maxillofacial area, experimental study, electron microscopy.

Relevance

The challenge of managing gunshot wounds and their long-term consequences has historically been, and continues to be, one of the most demanding and urgent problems in military and field surgery. Since the advent of gunpowder, firearms have undergone constant evolution, with successive generations of projectiles being engineered to deliver ever-greater destructive force.

Recent fundamental research in wound ballistics and bone tissue regeneration has shed light on the specific impact of high-energy projectiles on bone, revealing destruction at the micro- and ultrastructural levels,

as well as a potential influence on the rate and quality of bone consolidation [1,2]. Nevertheless, the precise nature of ultrastructural changes occurring in bone tissue during gunshot fractures remains incompletely understood [3,4,5,6].

The patterns of firearm injuries, the development of associated complications, and the clinical course of wound-related conditions with high mortality rates all reflect the use of ammunition with diverse projectile characteristics in combat settings. In light of this, numerous authors stress the importance of studying wound ballistics as a prerequisite for accurately evaluating injury profiles, determining appropriate surgical strategies, and elucidating the mechanisms underlying firearm trauma. The widespread adoption of modern small arms firing various projectile types at high muzzle velocities, combined with their unstable in-flight orientation, has altered wound ballistic patterns and contributed to a marked increase in injury severity [7,8,9].

Aim of the Study

The aim of the study was to investigate the ultrastructural changes in the skin and oral mucosa at the early stages following firearm and non-firearm jaw injuries.

To achieve this goal, the following **tasks** were set:

1. To study the ultrastructural changes in the skin and oral mucosa after firearm-induced jaw injury in experimental rats.
2. To study the ultrastructural changes in the skin and oral mucosa after non-firearm-induced jaw injury in experimental rats.

Materials and Methods

The study was conducted on seven adult Wistar rats divided into three groups: Group I — control (intact animal); Group II — experimental group with mechanically induced injury; Group III — experimental group with firearm-induced injury [1].

For electron microscopic examination, fragments of bone and soft tissue from the rat jaws were fixed in a 2.5% glutaraldehyde solution prepared in phosphate buffer at pH 7.4, followed by post-fixation in a 1% osmium tetroxide solution in the same buffer. The samples were then dehydrated through a graded ethanol series. Impregnation and embedding of the material were performed using a mixture of Epon–Araldite epoxy resins. Subsequently, ultrathin sections were contrasted according to the Reynolds method [2].

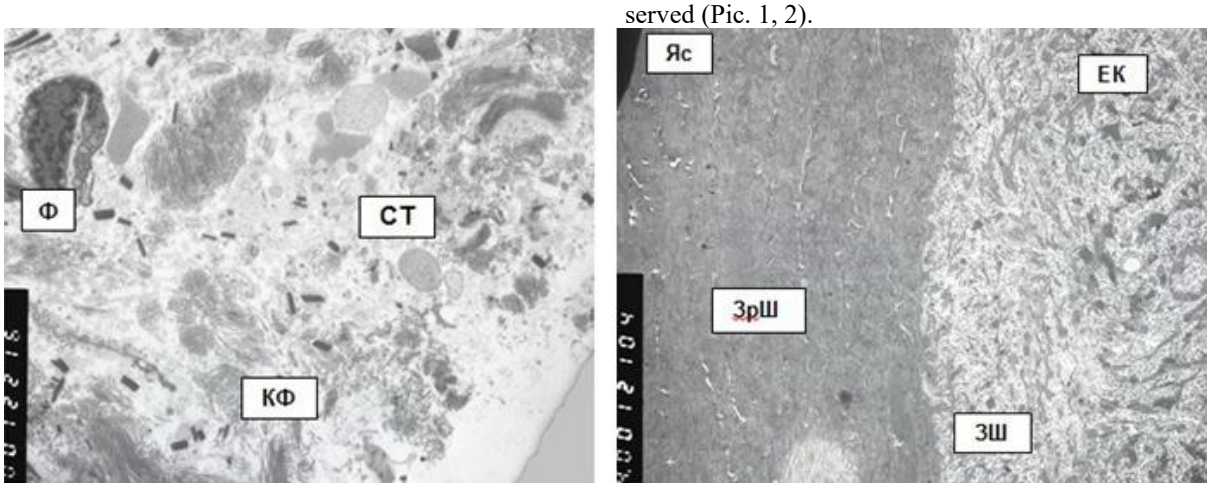
The specimens were examined and photographed using a PEM-100-01 transmission electron microscope (Ukraine). The study was carried out in the Electron Microscopy Group of the Laboratory for Pathological Anatomy and Electron Microscopy.

Results and Discussion

1. Examination of the condition of soft tissues in rats of the intact group

On the 7th day, in the connective tissue area of the skin of the intact rat, edema of the connective tissue ground substance was observed, along with a loose arrangement of collagen fibril bundles. Among these bundles, single erythrocytes, disrupted collagen fibril clusters, and spherical formations were identified, as well as fibroblasts with a well-developed granular endoplasmic reticulum, indicating enhanced collagen protein synthesis.

In the dense layer of the skin's connective tissue, slightly above the incision line, microvessels with dilated electron-lucent lumina and normal ultrastructure were found. Between tightly arranged collagen fibril bundles, large fibroblasts with evident signs of increased protein-synthesizing activity were also observed (Pic. 1, 2).

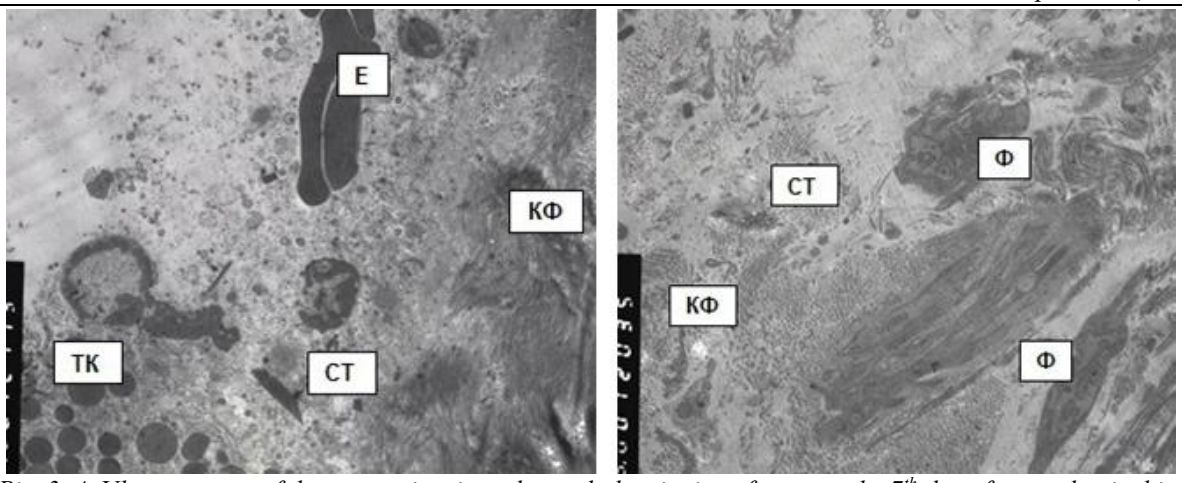


Pic. 1, 2. Ultrastructure of the connective tissue of an intact rat. ×3,000.
СТ — connective tissue; Ф — fibroblast; КФ — collagen fibrils; Яс — gingiva; ЕК — epithelial cell; 3рШ — keratinized layer of the epidermis; 3Ш — granular layer of the epidermis.

2. Results of modeling non-firearm mechanical injury in rats

On the 7th day after mechanical injury, edema of the connective tissue ground substance was observed in certain areas of the soft tissues of the rat, along with remnants of cellular debris, isolated damaged cells, erythrocytes, and clusters of mast cells. In the fracture zone, homogenization of the collagen fibrils in the dense connective tissue was noted.

Adjacent to the fracture site, fragments of collagen fibril bundles and large electron-lucent regions containing fibroblasts actively synthesizing collagen fibrils were observed (Pic. 3, 4).

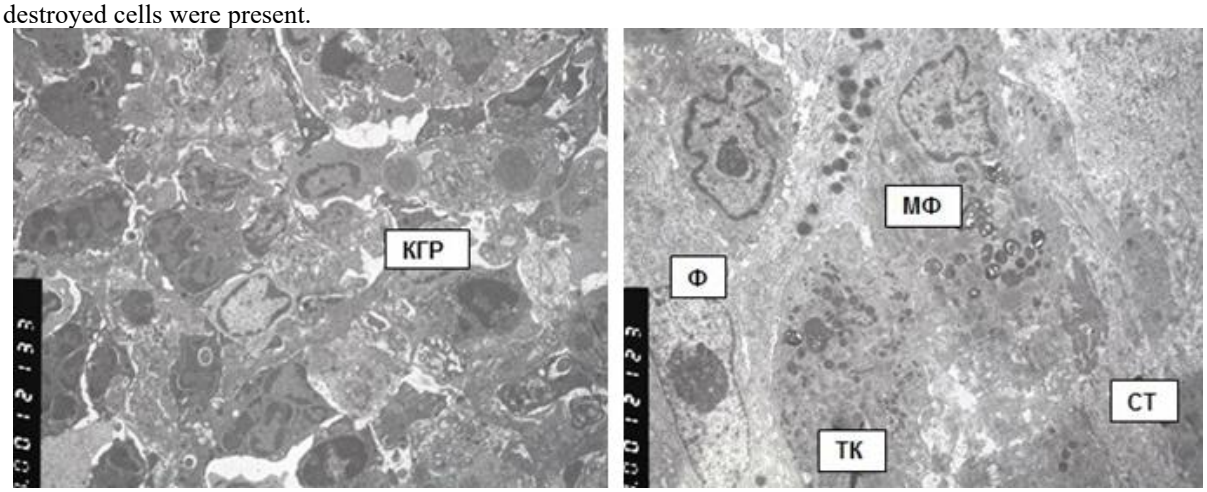


Pic. 3, 4. Ultrastructure of the connective tissue beneath the gingiva of a rat on the 7th day after mechanical injury. ×3,000.
CT — connective tissue; ТК — mast cell; E — erythrocyte; КФ — collagen fibrils.

3. Results of modeling firearm injury in rats

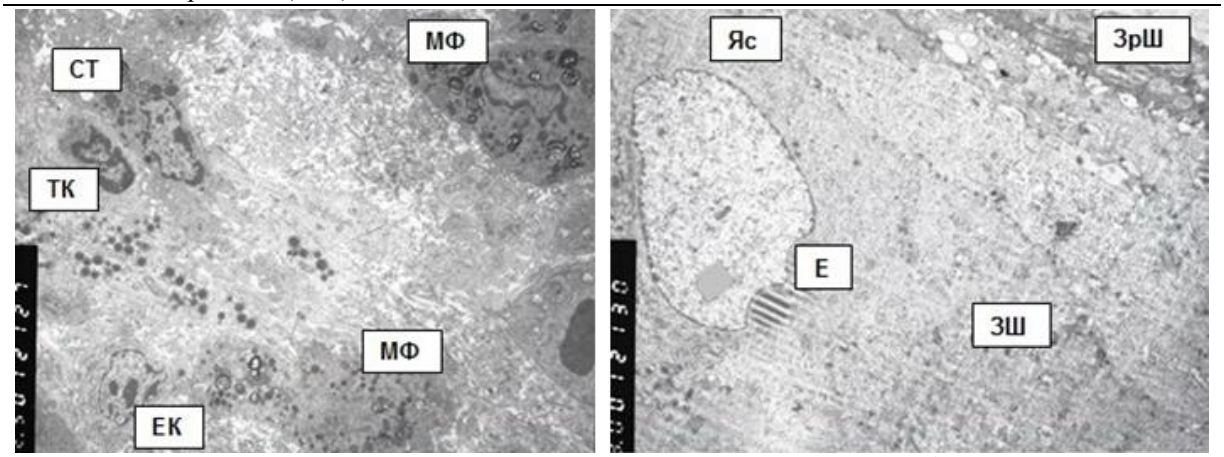
On the 7th day after the gunshot wound, accumulations of histiocytic-type cells were observed in certain areas of the soft tissue within the wound region, many of which were in a state of destruction and necrosis. Among these, leukocytes and macrophages predominated. Between them, cellular debris and remnants of destroyed cells were present.

In other areas of the gunshot injury site, leukocytes, erythrocytes, cells, and collagen fibrils in a necrotic state were identified, covering a large area. Numerous mast cells were observed in this region, some containing granules in a normal state, while others showed clear signs of degranulation (Pic. 5, 6).



Pic. 5, 6. Ultrastructure of the connective tissue beneath the gingiva of a rat on the 7th day after firearm injury. ×3,000.
КГР — histiogenic cells; CT — connective tissue; Ф — fibroblast; МФ — macrophage; ТК — mast cell.

Deeper within the connective tissue, large macrophages, epithelioid cells, and fibroblasts were also observed, exhibiting signs of active protein-synthesizing processes directed toward the production of collagen fibrils. In the superficial layers of the skin epithelium, widening of intercellular junctions and accumulation of vacuoles within the cells were noted (Pic. 7, 8).



Pic. 7, 8. Ultrastructure of the connective tissue beneath the gingiva of a rat on the 7th day after firearm injury. ×3,000.

СТ — connective tissue; МФ — macrophage; ТК — mast cell; ЕК — epithelioid cell; Ш — skin; Е — epithelium; ЗШ — granular layer; ЗрШ — keratinized layer.

Conclusions

The comparative study of ultrastructural changes in the soft tissue (skin) seven days after firearm injury and mechanical fracture demonstrated that firearm injury causes more pronounced manifestations of productive inflammation than mechanical trauma. The gunshot wound affected wider areas with destructive and necrotic changes in the soft tissues of rats compared with mechanical fracture.

These changes were characterized by the accumulation of a large number of histiogenic cells, predominantly macrophages and mast cells. Moreover, some mast cell granules exhibited signs of histamine release, indicating a reaction to an allergic component — possibly, in this case, to gunpowder residue from the firearm discharge.

In addition, after firearm injury, the tissues underwent extensive and severe damage, including destruction and necrosis of both connective tissue cells and collagen fibers. At the same time, an increased number of fibroblasts actively engaged in protein synthesis directed toward collagen production and collagen fibril formation were observed compared with mechanical trauma.

On the 7th day after firearm injury, productive inflammation in the proliferative phase with elements of reparative regeneration was noted in the soft tissues of rats. On the 7th day after mechanical fracture, the intensity of productive inflammation in the soft tissues was significantly lower than that observed after firearm injury.

References

1. Huliuk AH. Eksperymentalna model vohnepalnykh poshkodzhen shchelep u shchuriv [Experimental model of gunshot injuries of the jaws in rats]. Certificate of copyright registration No. 119858. 2023 Jun 19.

2. Reynolds ES. The use of lead citrate at high pH as an electron-opaque stain in electron microscopy. J Cell Biol. 1963;17:208–212.

3. Nguyen TN, Meek G, Breeze J, Masouros SD. Gelatine backing affects the performance of single-layer ballistic-resistant materials against blast fragments. Front Bioeng Biotechnol. 2020;8:744. Doi:10.3389/fbioe.2020.00744.

4. Velasco JM, Valderama MT, Margulieux K, et al. Comparison of carbapenem-resistant microbial pathogens in combat and non-combat wounds of military and civilian patients seen at a tertiary military hospital, Philippines (2013–2017). Mil Med. 2020;185(1–2):e197–e202. Doi:10.1093/milmed/usz148.

5. Kim TK. T test as a parametric statistic. Korean J Anesthesiol. 2015;68(6):540–546.

6. Valentine KP, Viacheslav KM. Bacterial flora of combat wounds from eastern Ukraine and time-specified changes of bacterial recovery during treatment in Ukrainian military hospital. BMC Res Notes. 2017;10(1):152. Doi:10.1186/s13104-017-2481-4.

7. Zarutskyi YaL, Khomenko IP, Verba AV, Burluka VV. Boiova khirurhichna travma. Voiennopolova khirurhiia [Combat surgical trauma. Military-field surgery]. In: Zarutskyi YaL, Bilyi Vya, editors. Kyiv: Feniks; 2018. P. 45–59.

8. Mishalov VD, Mykhailenko OV, Khokholieva TV, Petroshak Oyu. Sudovo-medychna ekspertyza obiektiv pry vohnepalnii travmi: monohrafiia (vydannia dopovnene) [Forensic medical examination of objects in gunshot injury: monograph (expanded edition)]. Kyiv; 2019. 303 p.

9. Shcherbak VV, Tolmachev OO, Kundius OV, Abdurasulov AA. Metodolohiia provedennia ballistychnoho eksperymentu na biolohichnykh imitatorakh tila liudyny [Methodology for conducting ballistic experiments on biological human body simulators]. Kryminalnyi Visnyk. 2015;24(2):131–132.

"HARMONIZING FORM AND SPIRIT": A STUDY ON THE REHABILITATION MECHANISM OF CHRONIC STRAIN IN VIOLIN PLAYING FROM THE PERSPECTIVE OF TRADITIONAL CHINESE MEDICINE

Wang Chenyu
Associate Professor
Zhang Ge
Assistant Lecturer
Graduate School of China Academy of Chinese Medical Sciences
Su Zhou, China
DOI: 10.5281/zenodo.19827928

ABSTRACT

Chronic strain in violin playing is a common issue that plagues the physical and mental health of performers. Its' essence is not only manifested as damage to the "Form" of the musculoskeletal system but also includes injury to the "Spirit," such as performance concentration, artistic expression, and professional identity, presenting a state of "disease of both Form and Spirit." Based on the Traditional Chinese Medicine concept of "Unity of Form and Spirit," this study systematically elucidates the connotation and mechanism of the "Harmonizing Form and Spirit" theory in the rehabilitation of chronic strain in violin playing. By analyzing the "Form-Spirit" characteristics of performance strain, this paper proposes a dual-track treatment approach of regulating Form and calming Spirit, constructing a comprehensive rehabilitation program encompassing manual intervention, Daoyin training, and psychological adjustment. The study suggests that "Harmonizing Form and Spirit" aligns with the performer's professional characteristics integrating "technique, artistry, body, and mind." It can alleviate local symptoms while restoring the overall coordination of performance function and the unimpeded state of artistic expression, providing a new theoretical perspective and practical pathway for the rehabilitation of occupation-related disorders in instrumental performance.

Keywords: Violin Playing, Chronic Strain, Harmonizing Form and Spirit, TCM Rehabilitation, Psychosomatic Treatment.

I. The "Form-Spirit" Characteristics of Chronic Strain in Violin Playing

(I) Manifestations of "Form Damage" in Performance Strain

Chronic strain caused by violin playing is by no means an isolated physiological lesion but a profound state of damage to both "Form and Spirit." At the level of "Form", the performer's body is reshaped by the instrument, presenting an unnatural, distorted elegance. To secure the instrument, the neck must be persistently twisted to the left, with the jaw and shoulder applying significant static force to hold the violin. This can easily lead to temporomandibular joint disorders, cervical spine segment deformation, and even hyperosteogeny of the clavicle—a "professional mark." The left arm is forced into a position of shoulder external rotation and extreme forearm pronation. The ulnar deviation movement pattern of the left hand significantly increases the risk of injury, leading to bursitis, tendinitis, and various nerve entrapment syndromes. To compensate for this imbalance, the spine may develop pelvic rotation and lumbar lordosis, ultimately resulting in uneven shoulders and chronic back pain. This represents the "Form" alteration of the physical body under long-term forced posture.

However, the more subtle damage lies in the depletion of "Spirit." Chronic strain is not merely physical pain of muscles and fascia but is internalized as persistent tension in the performer's nervous system and subtle dysfunction in motor control. Due to long-term, highly repetitive, high-precision fine movements, some performers may develop occupational dystonia—a movement disorder syndrome caused by incoordination between agonist and antagonist muscles, characterized by abnormal muscle tone and involuntary postures. This manifestation of "Spirit" disorder—uncontrollable tonic spasms in the fingers during performance—often signals the end of a performing career. Furthermore, intense practice schedules and competitive pressure keep the body in a constant state of stress. Even in comfortable environments, performers struggle to escape mental burdens, exacerbating muscle tension and delaying recovery. This interaction between "Form" and "Spirit" transforms the performer from a creative subject of art into a carrier "disciplined" by the instrument, losing their inherent coordination and composure.

(II) The Dimension of "Spirit Injury" in Performance Strain

Compared to visible musculoskeletal deformities, the "Spirit injury" caused by violin playing is a more subtle yet corrosive harm. It is not merely psychological fatigue but a functional depletion of the performer's nervous system under long-term precision control, a spiritual scar left behind after the intense struggle between artistic pursuit and physical limits.

This "Spirit injury" first manifests as the alienation of motor control. When performers devote their entire mind and spirit to musical expression, neurons in the motor cortex of the brain must dispatch each finger's flexion and extension with extreme frequency. Long-term, high-intensity repetition can lead to functional disturbances in certain neural circuits due to excessive excitation—this is where occupational dystonia takes root. Fingers no longer obey the will, suddenly cramping during critical musical phrases, as if seized by a mysterious force. This is the "Spirit's" betrayal of

the "Form," a loss of control, capable of destroying a performer's artistic life.

A deeper layer of "Spirit injury" hides within the daily neural tension. Continuous practice stress and performance anxiety keep the performer's sympathetic nervous system in a state of high alert. Even during rest, the body cannot truly enter a relaxation mode. This pervasive neural tension continuously reinforces defensive muscle contraction, hindering local blood circulation and trapping the strain in a vicious cycle that is difficult to reverse. The performer gradually loses harmonious communication with their body, descending into fear of pain, anxiety over mistakes, and a compulsive pursuit of "perfect" performance. The inherent freedom and joy of art are alienated into a struggle against one's own physical self.

Ultimately, this "Spirit injury" manifests as a profound existential fatigue. The body is no longer a medium for the soul's expression but an object requiring constant monitoring and resistance. Though performers can produce beautiful notes, they lose the ease and composure inherent to playing, experiencing, in the rift between spirit and form, the internal desolation of the creative subject being instrumentalized.

II. Theoretical Connotation and Rehabilitation Mechanism of "Harmonizing Form and Spirit"

(I) The Physiological Basis of "Unity of Form and Spirit"

The state of "Unity of Form and Spirit" in violin playing is not an elusive philosophical concept but is built upon a precise and demonstrable physiological foundation. Central to this foundation is the establishment of an efficient, coordinated interaction between the performer's nervous system and motor system.

At the "Form" level, performance requires different body parts to work synergistically according to biomechanical optimization principles. The spine, as the central axis, must provide elastic and stable support, enabling the head, neck, shoulders, and arms to form a cohesive yet flexible unit. The rotation of the shoulder joint, flexion and extension of the elbow, adjustment of the wrist, and fine pressing of the fingers together constitute a multi-degree-of-freedom kinetic chain. Within this chain, large muscle groups are responsible for force transmission and support, while small muscle groups handle millimeter-level precision control. This coordination of "Form" relies on continuous feedback from the proprioceptive system—receptors in muscles, tendons, and joints constantly transmit positional and tension information to the central nervous system, allowing the performer to perceive the relative relationship between the strings and fingers without relying on sight.

The intervention of "Spirit" is embodied in the efficient integration and regulation of this motor system by the central nervous system. When a performer holds a musical intention, the premotor cortex and supplementary motor area of the cerebral cortex begin planning action sequences. The basal ganglia are responsible for selecting and initiating appropriate motor programs, while the cerebellum fine-tunes timing and amplitude. The pyramidal tract transmits these instructions to the anterior horn motor neurons in the spinal cord. ultimately driving muscles to produce precise contractions. Notably, long-term systematic training induces "functional reorganization" in this process: complex actions that initially required conscious monitoring gradually descend to the level of the basal ganglia and cerebellum, transforming into nearly automated motor programs. This process of "de-automatization" based on neural plasticity is the fundamental prerequisite for "Spirit" to be liberated and focused on musical expression.

When the biomechanical efficiency of "Form" and the neural regulatory efficiency of "Spirit" achieve a high degree of unity, the performer enters the state of "Unity of Form and Spirit"—where intention becomes action, action becomes sound, and the body becomes a natural conduit for musical flow.

(II) The Rehabilitation Mechanism of "Regulating Form"

"Regulating Form," as a rehabilitation mechanism for chronic strain in violin playing, focuses on actively reshaping the performer's body structure and function, which have become imbalanced due to long-term forced posture. The goal is to return "Form" to an optimized biomechanical state, thereby creating the material prerequisite for the liberation of "Spirit."

The strain in violin playing originate" fro" the alienation of "Form"—the chronic leftward neck rotation for holding the violin, the elevation and adduction of the left shoulder, compensatory scoliosis, and restricted thoracic mobility. These postures, seemingly serving art, are in fact a continuous deviation from the body's natural structure. The first step in "Form-regulating" rehabilitation is to release and restore this alienated "Form." Through targeted myofascial release techniques, the fibrous adhesions and high tension in the upper trapezius, sternocleidomastoid, and levator scapulae muscles are relieved. Joint mobilization techniques restore the range of motion lost in the cervical spine, thoracic spine, and scapula after long-term locking. This process is akin to recalibrating a deformed instrument to correct intonation. Its purpose is to clear pathological accumulation at the "Form" level, releasing the body from rigid functional lock-down and restoring usable space for movement.

However, the true essence of "Regulating Form" lies not in passive release but in active re-education. Through years of playing, the performer's body has formed deeply ingrained "erroneous memories"—the motor cortex and basal ganglia have encoded that asymmetrical, energy-intensive playing posture as an automatic program. Therefore, "Form-regulating" rehabilitation must guide performers in conscious movement reconstruction. This includes: rebuilding dynamic spinal stability support through training of the core muscles and deep neck flexors, transforming the force of holding the violin from mere neck clamping to lightweight support transmitted through the entire core; correcting the elevated and protracted shoulder posture through scapular retraction, depression, and humeral external rotation training, creating more spacious movement for the arm; restoring the suppressed breath-

ing amplitude through thoracic expansion and intercostal muscle activation exercises, optimizing oxygen supply and neural tension during performance.

Crucially, “Regulating Form” pursues “effortlessness” rather than “forcefulness.” Many strains in violin playing stem from performers using excessive muscular force—holding the violin too tightly, pressing the strings too hard, gripping the bow too firmly. The deeper goal of “Form-regulating” rehabilitation is to help performers find the path of “minimal work,” allowing gravity, skeletal support, and elastic tension to replace unnecessary muscle contraction. When the body learns to support the instrument in a more structurally efficient way, when the timing and sequencing of movements become rational, the heavy, consuming "Form" gradually transforms Into a light, permeable "Form."

Ultimately, the outcomes of “Form regulation” feed back into the state of “Spirit.” When the body ceases to be a burdensome object requiring constant monitoring, when movements become effortless and natural, the performer’s mind and spirit are freed from the fear of pain and a’xiety about technique. At this point, "Form" is no lo’ger a limitation to expression but becomes a natural chan’el for musical flow, and "Regulating Form" comp’etes its foundational return to the “Unity of Form and Spirit” through bodily reconstruction.

(III) The Rehabilitation Mechanism of “Regulating Spirit”

“Regulating Spirit,” as a rehabilitation mechanism for chronic strain in violin playing, focuses on intervening at the level of the nervous system. It aims to repair the central functional disorders caused by long-term, high-intensity precision movement and performance pressure, allowing “Spirit” to return to its inherent state of composed command and effortless regulation, thereby providing neural-level assurance for the complete liberation of "Form."

The “Spirit injury” in performance strain is essentially a functional exhaustion and regulatory failure of the nervous system. Long-term high-intensity fine motor training leads to excessive excitation in specific neuron clusters in the motor cortex. This persistent neural hyperactivity can ultimately result in an imbalance between excitation and inhibition, even triggering coding disorders of motor programs in the basal ganglia and cerebellum. Concurrently, performance stress and anxiety chronically activate the sympathetic nervous system, placing the body in a state of constant stress. This pervasive neural tension, in turn, reinforces defensive muscle contraction, trapping the strain in a vicious cycle difficult to reverse. The primary task of “Spirit-regulating” rehabilitation is to break this cycle.

The pathway to "“egulating Spirit""begins with recalibrating perception. Through practices like mindful body scanning and breath awareness, performers are guided to shift their attention from threat signals like “pain” or “mistakes” towards a neutral, holistic bodily sensation. This shift in perceptual mode can reduce excessive activation in the amygdala, allowing the brain to disengage from anxiety-driven defense modes and enter a state of safety and acceptance. When performers no longer maintain fear-based vigilance over bodily signals, the autonomic nervous system can switch from sympathetic dominance to parasympathetic dominance, creating physiological conditions for deep muscle relaxation and tissue repair.

Deeper “Spirit regulation” targets the neural remodeling of motor control. For performers already experiencing motor program disorders, techniques leveraging mirror neuron mechanisms and motor imagery training are used to re-input correct movement patterns into the brain. Through slow, segmented, highly focused practice, the motor cortex and basal ganglia gradually rebuild the distorted action representations. The essence of this training is guiding the “Spirit” with clear awareness to regain control of the “ody mi”led by automatic programs—not by forcibly suppressing symptoms, but by replacing old erroneous neural connections with new, correct ones.

As “Spirit” gradually returns to its’ original role of composed command, the performer’s internal experience undergoes a profound transformation. The pervasive neural tension and anxious monitoring of the body begin to dissolve, replaced by a relaxed yet focused “presence.” At this point, “Spirit” is no longer a tool coercing the body to achieve goals but becomes the awareness itself, dancing in coordination with the body. The joy of performance returns, and "Form," under the composed direction of “Spirit,” regains the possibility of ease and freedom.

(IV) The Synergistic Effect of “Harmonizing Form and Spirit”

“Harmonizing Form and Spirit” is central to rehabilitating chronic strain in violin playing because “Form” and “Spirit” are inherently two aspects of a single entity within performance activity. They interact and together constitute a dynamic functional system. When rehabilitation interventions target both “Form” and “Spirit” levels, they produce a synergistic effect surpassing single-modality therapies, enabling the performer’s body and mind to achieve holistic restoration through bidirectional interaction.

From a physiological perspective, “Form regulation” provides the material basis for “Spirit regulation.” When myofascial release, joint mobility training, and movement pattern reconstruction release high muscle tension and correct skeletal misalignments, the quality of proprioceptive input from the body changes fundamentally. The "pain signals" and "tension signals" flooding the afferent neural pathways gradually diminish, replaced by neutral, fluid positional and movement information. This optimized sensory input creates conditions for recalibrating the central nervous system—the brain no longer expends significant resources monitoring threatening signals from the body, allowing it to disengage from defense mode and shift towards finer motor control and freer musical expression.

From a neural perspective, “Spirit regulation” provides the central guarantee for consolidating “Form regulation.” When mindfulness practices reduce sympathetic overactivation and motor imagery rebuilds distorted motor programs, the performer’s central control becomes stable and efficient. This optimized neural output allows peripheral muscles to work with better

timing and more appropriate force, avoiding compensatory tension and coordination breakdown caused by neural stress. The composure of "Spirit" makes "Form's" movements more effortless; the ease of "Form" further reduces the burden on "Spirit"—the two reinforce each other in a virtuous cycle.

III. Constructing a "Harmonizing Form and Spirit" Rehabilitation Program

(I) Rehabilitation Assessment: Dual-Dimensional Diagnosis of Form and Spirit

Rehabilitation assessment for chronic strain in violin playing must transcend simple medical imaging and physical examinations to establish a "Form-Spirit Dual-Dimensional" diagnostic framework. Only by simultaneously examining structural bodily imbalances and neural regulatory disorders can the full picture of the strain be revealed, providing a foundation for precise rehabilitation.

Assessment in the "Form" dimension focuses on biomechanical changes. This includes: assessing the performer's static postural patterns through observation and palpation—identifying structural compensations like forward head posture, uneven shoulders, scoliosis, and pelvic rotation,detecting restrictions in key movements such as cervical rotation, scapular sliding, and forearm supination through range of motion and muscle length tests; locating fibrosis and high-tension points in muscle groups like the upper trapezius, sternocleidomastoid, and flexor carpi ulnaris through palpation and tenderness mapping. Additionally, dynamic assessment should observe movement coordination patterns during instrument holding and bowing—identifying functional abnormalities like compensatory shoulder shrugging, excessive finger pressure, and breathing rhythm disturbances.

Assessment in the "Spirit" dimension delves into neural regulation and psychological function. This includes: detailed history-taking to understand the timing, aggravating factors, and relationship to performance of pain and motor dysfunction, identifying early signs of occupational dystonia—uncontrolled spasms or stiffness in fingers during specific actions, assessing neural tension to evaluate if the brachial plexus, median nerve, ulnar nerve, etc., show increased tension or restricted gliding due to chronic entrapment,evaluating psychological state to understand the performer's anxiety level, fear-avoidance beliefs regarding pain, and bodily awareness—whether they have fallen into an adversarial relationship with their body.

The essence of the "Form-Spirit Dual-Dimensional" assessment lies in identifying the interaction between the two. For example, chronic neck muscle tension can lead to chronic entrapment of the brachial plexus, causing finger paresthesia and motor control issues. Conversely, performance anxiety can continuously activate the sympathetic nervous system, exacerbating defensive muscle tension in the neck and shoulders. Only by placing "Form" imbalances and "Spirit" disturbances within the same diagnostic framework can the internal logic of the strain be revealed, guiding targeted "Harmonizing Form and Spirit" rehabilitation interventions.

(II) "Form-Regulating" Rehabilitation Techniques

"Form-regulating" rehabilitation techniques aim to restore the performer's biomechanical balance, reshaping the "Form" alienated by long-term forced posture through a combination of active and passive methods.

In passive intervention, myofascial release and joint mobilization are primarily used. For high-tension points in the neck trapezius, sternocleidomastoid, and forearm flexors, sustained pressure and transverse friction are applied to release fibrous adhesions and restore muscle elasticity and gliding. Simultaneously, gentle mobilization is performed on the cervical spine locked in rotation, the elevated and protracted scapula, and restricted costosternal joints to gradually restore joint range of motion, creating space for movement reconstruction.

Active training is the core of "Form regulation." By activating deep neck flexors and core muscles, dynamic spinal stability is rebuilt, transforming the force of holding the violin from "local clamping" to "whole-body transmission." Scapular retraction, depression, and humeral external rotation exercises correct the compensatory shoulder shrugging pattern during playing, opening up a spacious movement channel for the upper limb. Additionally, using resistance bands and segmented movement exercises, erroneous motor programs are re-encoded, teaching the body to play with "effortlessness" rather than "force." When skeletal support replaces muscle tension, and movements shift from heavy to light, "Form" returns to its' natural state of ease.

(III) "Spirit-Regulating" Rehabilitation Techniques

"Spirit-regulating" rehabilitation techniques focus on repairing the regulatory functions of the central nervous system, using perception reshaping and motor relearning to relieve the "Spirit's" excessive monitoring and anxious projection onto the body.

At the perceptual level, mindful body scanning and breath awareness practices are used to guide performers to shift attention from localized pain signals to holistic bodily sensations. This decentered awareness can reduce excessive amygdala activation, allowing the autonomic nervous system to switch from the combat mode of sympathetic dominance to the relaxation mode of parasympathetic dominance, creating internal space for deep neural repair. Simultaneously, leveraging mirror neuron mechanisms, performers are guided to observe and mentally rehearse smooth, coordinated playing movements, re-inputting correct motor representations into the brain.

At the motor level, for performers with existing motor program disorders, slow, segmented training and motor imagery therapy are employed. By repeating fundamental movements at extremely slow speeds with high focus, the motor cortex and basal ganglia gradually establish new neural connections, replacing the old patterns distorted by automatic programs. When performers learn to regain control of their movements with clear awareness, rather than being driven by fear and anxiety, "Spirit" returns from disorder to its original

state of composed command, and the fluency and joy of performance are reborn.

(IV) Sequential Treatment Model of "Harmonizing Form and Spirit"

The sequential treatment model of "Harmonizing Form and Spirit" is a staged, systematic rehabilitation pathway constructed based on the pathological evolution pattern of chronic strain in violin playing, where "Form damage affects Spirit, and Spirit injury hinders Form." This model emphasizes the priority, sequence, and dynamic progression of interventions, allowing "Form regulation" and "Spirit regulation" to have different emphases at various stages while supporting each other, ultimately achieving the synergistic return of overall function.

The initial phase uses "Regulating Form" as a precursor to create conditions for settling the "Spirit." At the onset of strain, performers are often trapped by intense localized pain and muscle tension. Their mind and spirit are entirely captured by the "pain sensation," locked in a vicious cycle of fear and anxiety. Forcibly attempting "Spirit regulation" at this stage would be futile. Therefore, this phase focuses on passive release and physical therapy—using myofascial techniques to release adhesions in the trapezius and sternocleidomastoid, using joint mobilization to restore restricted cervical and scapular range of motion. When intense physiological pain signals diminish and the body is initially released from chronic locking, threatening sensory input to the central nervous system is significantly reduced, allowing the brain the basic conditions to shift from defense mode to perceptual awareness.

The middle phase shifts to using "Regulating Spirit" as the pivot to consolidate and deepen rehabilitation outcomes. Once the physical structure stabilizes and pain becomes manageable, the focus turns to neural regulation and motor relearning. Mindful breathing and body scan training guide performers to re-establish neutral dialogue with their bodies, reducing sympathetic overactivation. Slow, segmented practice and motor imagery therapy repair distorted motor programs and remodel neural connections in the motor cortex and basal ganglia. At this stage, the composed command of "Spirit" begins to replace the passive tension of "Form," and the performer's internal experience shifts from resisting pain to being aware of movement.

The later phase emphasizes "Simultaneous Regulation of Form and Spirit" to achieve integration in dynamic action. When the body possesses the correct structural foundation and the nervous system has established efficient control patterns, treatment enters the integration phase. Within a complete performance context, performers are guided to use their rehabilitated bodily awareness to experience the fluency of musical expression, allowing the ease of "Form" and the focus of "Spirit" to achieve a new unity in authentic artistic behavior. At this point, rehabilitation is no longer a technique for symptom elimination but a process of helping performers rediscover the "Unity of Form and Spirit" in playing, realizing the true rebirth of their artistic life.

Conclusion

In summary, chronic strain caused by violin playing is not merely mechanical damage to the musculoskeletal system but the result of a dual alienation of "Form" and "Spirit" formed during the performer's long-term artistic practice. Imbalance in "Form" manifests as a systemic biomechanical disorder, reducing the body to a vessel disciplined by the instr'ment. Depletion of "Spirit" manifests as functional obstacles in neural regulation, trapping the performer in self-conflict and anxiety. The two interact, forming the internal logic that makes strain difficult to reverse.

The "Harmonizing Form and Spirit" rehabilitation mechanism proposed in this study is based on a deep insight into this pathological essence. "Regulating Form" uses release and reconstruction as methods to return the body to a centered, comfortable structural state. "Regulating Spirit" uses perception and relearning as pivots to enable the mind and spirit to regain their capacity for composed command. The two follow sequentially and progress dynamically in the treatment process, ultimately achieving a synergistic effect in the integration phase. When the ease of "Form" and the focus of "Spirit" are reunified in the act of playing, the performer is no longer a laborer constrained by their body but an expressive being united with their instrument.

The core essence of "Harmonizing Form and Spirit" lies in the fact that it never views rehabilitation as mere technical repair but understands it as a holistic restoration of the performer's life state. When the body once again becomes a natural channel for musical flow, when the mind and spirit are no longer obscured by pain and anxiety, the inherent freedom and joy of authentic performance are reborn—this is both the healing of strain and the true renaissance of artistic life.

References

1. Kloppel R. The physiological and psychological essentials of performing arts[M]. Shanghai: Shanghai Music Publishing House, 2009.

2. Zhao Y C. Regulating body, mind, breath, and gravity bowing: An analysis of Erhu playing principles from the perspectives of physiology, psychology, and biomechanics[J]. Music Learning and Research, 1989(2): 2-13.

3. Feng X G. Reflections on the scientific nature of research in music performance art[J]. Journal of Nanjing Arts Institute, 2003(1): 90-94.

4. Deng S X, Wang J, Qiao D C. Exercise physiology[M]. Beijing: Higher Education Press, 2009.

5. Shen Z, Lin S Z. Physiological psychology[M]. Beijing: Peking University Press, 2007.

6. Qi F J. Nourishing essence, Qi, and spirit through Daoyin and massage[M]. Wuhan: Hubei Science and Technology Press, 2015.

7. Dong L R. TCM somatopsychic disease theory[M]. Beijing: Guangming Daily Press, 1991.

8. Hays K F. The enhancement of performance excellence among performing artists[J]. Journal of Applied Sport Psychology, 2010, 11(2): 299-312.

9. Bascomb J S. Performing arts and performance anxiety[D]. Huntington: Marshall University, 2019.

10. Tomporowski P D, Pesce C. Exercise, sports, and performance arts benefit cognition via a common process[J]. Psychological Bulletin, 2019, 145(9): 929-951.

PEDAGOGICAL SCIENCES

THE LEVEL OF DEVELOPMENT OF EDUCATIONAL COMPETENCIES: IMPLEMENTATION IN CURRICULUM MATERIALS

Ismayilova A.
Baku State University, Baku, Azerbaijan
DOI: 10.5281/zenodo.19827946

ABSTRACT

Changes in the global society and the rapid advancement of Information and Communication Technologies (ICT) necessitate fundamental changes in the teaching process, as well as the structure and content of education. Many countries view the educational system as a primary component of both social and personal development. A **competency-based approach** is considered a promising solution to many existing challenges in this field. To foster student competencies and improve the quality of the instructional process, curricula, planning models, and subject-specific standards are being re-evaluated. Interdisciplinary connections and their role in competency development are being assessed, leading to the design of new subject curricula. Currently, educational reforms in Azerbaijan are based on a **result-oriented approach**. As a outcome of the learning process, it is intended that learners develop broader competencies alongside specific knowledge, skills, and habits.

Keywords: Information and Communication Technologies (ICT), competency, educational reforms in Azerbaijan, learning process knowledge, skills, and habits.

Defining Competence

The concept of "competence" is central to curriculum reform. Understanding the essence of competencies is vital for the correct implementation of learning objectives. Successful implementation results in a well-planned and effectively managed classroom process. **Competence** is the synthesized application of knowledge, skills, habits, qualities, and values.

Key Competencies (European Council, 2006):

1. Communication in the mother tongue.
2. Communication in foreign languages.
3. Mathematical literacy and basic competencies in science and technology.
4. Digital competence (ICT usage).
5. Learning to learn.
6. Social and civic competencies.
7. Sense of initiative and entrepreneurship.
8. Cultural awareness and expression.

These competencies form the basis for **21st-century skills**. The skills outlined in the State Standards for General Education of the Republic of Azerbaijan are fundamentally based on these competencies.

Theoretical Development and Paradigms

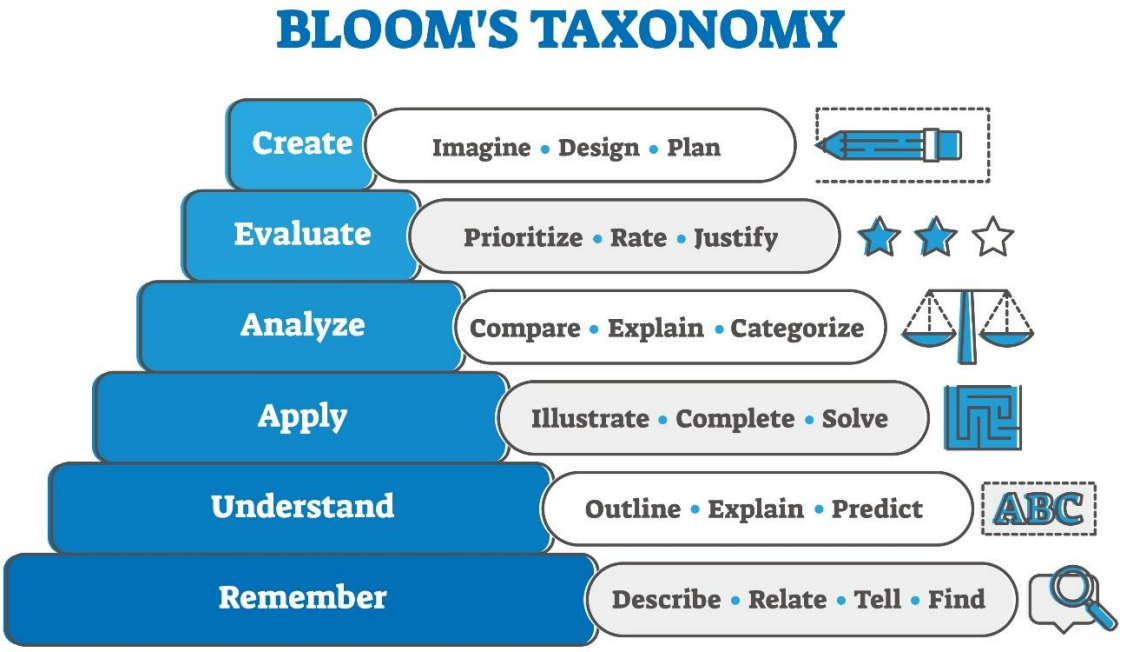
At the turn of the 21st century, the nature of learning shifted toward "independent personal development." Since 2010, educational paradigms have changed globally, influenced by researchers like V.I. Baydenko, G.B. Kornetov, and A.N. Novikov. T. Kuhn noted that paradigms do not just foster planning skills but enable the execution of those plans. K. Bailey suggests that competence is the form of a paradigm that encapsulates social and interactive characteristics.

The history of competence development consists of three stages:

- **Stage I (1960–1970):** Emergence and development of "competence" as a term.
- **Stage II (1970–1990):** Development of competence as a conceptual framework.
- **Stage III (Early 1990s – present):** Integration of competence as a core educational component.

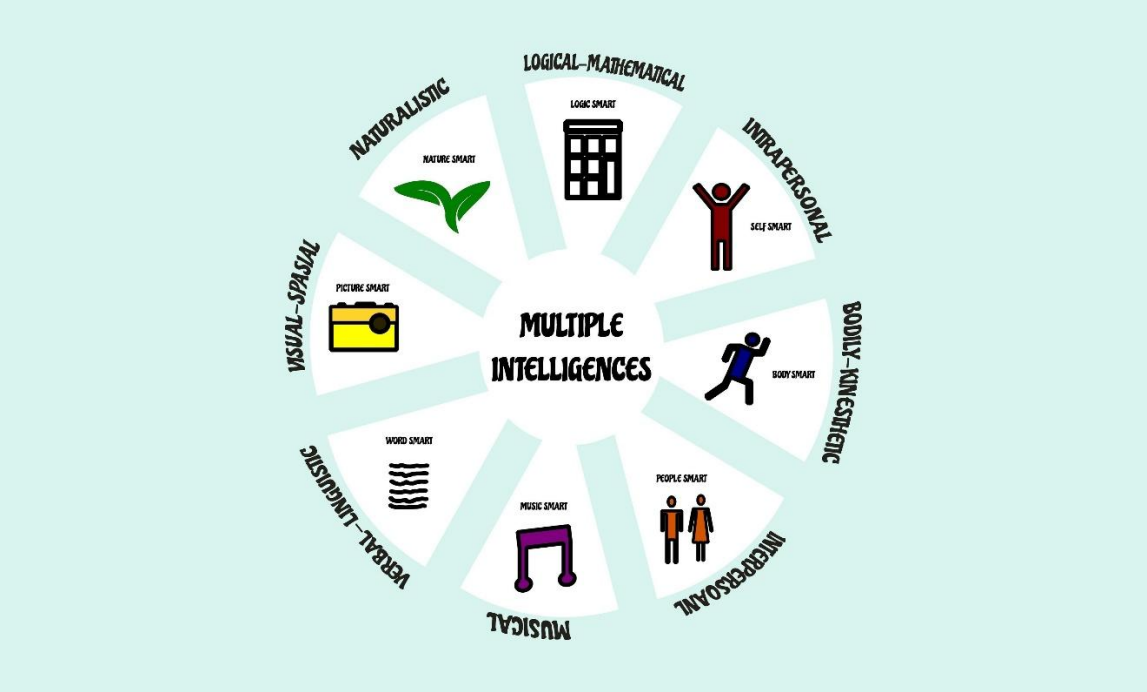
Psychological and Pedagogical Approaches

- **A.V. Khutorskoy:** Defines competence as an integrative quality of a person (knowledge, skill, value) directed toward self-realization.
- **B.I. Hasan:** Distinguishes between the two, stating that **competence** is the goal (objective), while **competency** is the result (realization).
- **Bloom's Taxonomy:** Learning is categorized into three domains: Cognitive (logic/decision making), Emotional (personal attitude/critical approach), and Psychomotor (physical/creative activity).



Shutterstock
Explore

- **Howard Gardner's Multiple Intelligences:** Emphasizes individualized instruction to prevent knowledge from being forgotten. Intelligence types include Verbal-Linguistic, Logical-Mathematical, Bodily-Kinesthetic, Musical-Rhythmic, Interpersonal, Intrapersonal, and Naturalistic.



Shutterstock

1.2 Implementation in Azerbaijan's History Education

Research by Azerbaijani scholars (e.g., M. Amirov, I. Jabrayilov, D. Musayev) highlights that developing student competencies is directly linked to the **teacher's own competency**. In the context of teaching the **History of Azerbaijan**, the following must be prioritized:

- **Knowledge:** Fostering a critical approach to historical development and personal interpretations of events.
- **Skills and Habits:** 1. **Cognitive Skills:** Developing logical perception and the ability to analyze controversial historical issues. 2. **Historical Evaluation:** The capacity to judge historical processes objectively. 3. **Source Analysis:** Working with primary

sources, visual aids (maps, photos, films), and audio-visual tools to build historical intuition. 4. **Independent Inquiry:** Fostering the ability to conduct independent research and make autonomous decisions during the discussion of controversial matters.

Conclusion

Analysis of pedagogical, psychological, and methodological literature shows that while the problem is theoretically explored in Azerbaijan

Key Educational Skills and Values

- **Decision-Making:** Ability to make informed decisions and defend them effectively.
- **Communication:** Ability to demonstrate one's position clearly and fluently within a group.

Values to be Cultivated:

- Cooperation, Integrity, and Sincerity.
- Adherence to rules and Responsibility.

Patriotism and Respect for national history and labor.

Classification of Skills in Curriculum Materials

I.ading Skills

The learner:

- Reads to acquire information.
- Identifies the main idea based on chapters, sections, and subheadings.
- Distinguishes key facts and clarifies the author's'position.
- Interprets results, explains causes, and analyzes texts using illustrations and primary sources.

II. Research Skills

The learner:

- Investigates and classifies information.
- Interprets data based on cause-effect relationships and comparisons.
- Applies information using illustrations or internet resources.
- Performs analysis, synthesis, and evaluation of data.

III. Independent Decision-Making Skills

The learner:

- Identifies legal issues and their consequences.
- Determines various strategies for problem-solving.
- Establishes essential criteria and organizes discussions to find compromises.

IV. Participation Skills

The learner:

- Expresses opinions on various social issues and demonstrates public activism.
- Strives for the protection of human rights.

Grade-Specific Requirements (History of Azerbaijan)

- **Grade VII:** Working with chronology, preparing diagrams/tables, comparing historical events and figures, working with primary sources, and tracing the development of national-spiritual values.
- **Grade VIII:** Preparing synchronous tables, evaluating the impact of Azerbaijan's geographical position on its political status, interpreting the activities of historical figures, and assessing cultural achievements within political processes.

1.3 Didactic, Psychological, and Philosophical Foundations of Competency Formation

The primary goal of modern history education is the development of the student's'personality. This involves transforming learners into active subjects of education by fostering creativity, cognition, and independent thinking.

Cognitive and Psychological Foundations

The learning process begins with **living perception**, where students understand the world through sensory organs. In history education, sensations, perceptions, and imagination are vital.

- **Thinking (Cognition):** Facilitates the understanding of the essence of events.
- **Comprehension:** New skills are formed based on previously acquired knowledge. Teachers act as facilitators in this process through analysis, synthesis, and comparison.
- **Inference:** * *Inductive Reasoning:* Moving from specific facts to general conclusions (e.g., observing the rise of cities in the 9th–11th centuries to conclude the general development of trade).
  - *Deductive Reasoning:* Moving from general concepts to specific instances (e.g., analyzing 18th-century khanates to conclude the existence of feudal fragmentation).

Stages of Psychological Readiness:

2. Preparation for perception.
3. Perception and understanding of information.
4. Generalization and transformation into knowledge.
5. Consolidation and application of skills.
6. Analysis of results.

Philosophical and Didactic Foundations

Historical truth is rooted in philosophy. Analyzing historical facts (such as feudal land obligations) allows students to assign historical value to a period. Art and literature (e.g., works by Khaqani Shirvani or Shah Ismail Khatai) also serve as vital sources for perceiving the social relations of the 11th–16th centuries.

Key Didactic Principles:

- Scientific accuracy and visual representation.
- Systematic progression and consistency.
- Integration of knowledge with practical activity.
- Consideration of students' 'ge, individual interests, and psychological development.
- Effective facilitation by the teacher to encourage cognitive activism.
- Use of intra-disciplinary integration and accessibility.

References

1. Republic of Azerbaijan. (2013). *State Strategy for the Development of Education in the Republic of Azerbaijan.* Baku, pp. 1-14.

2. Babbie, E. R. (2012). *The Practice of Social Research.* Belmont, CA: Wadsworth.

3. Belotserkovsky, A. V. (2008). Self-regulating organizations in higher professional education:

"Wather forecast." *Higher Education in Russia*, No. 12, pp. 3-9.

4. Bookman, J. (2010). Legislators stand on college steps to bar entry. *Atlanta Journal-Constitution*, 1(1), pp. 25-27.

5. Browne, M., & Keeley, S. (1986). *Asking the Right Questions: A Guide to Critical Thinking.* Englewood Cliffs, NJ: Prentice Hall.

6. Casner-Lotto, J., & Benner, M. W. (2006). *Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st century United States workforce.* New York: The Conference Board, Inc., Partnership for 21st Century Skills, Corporate Voices for Working Families, & Society for Human Resource Management. Retrieved from http://www.p21.org

7. Charles, L., Campbell, Jr., & Kresyman, S. (2015). Aligning Business and Education: 21st Century Skill Preparation. *e-Journal of Business Education & Scholarship of Teaching*, Vol. 9, Iss. 2, pp. 13-27. http://www.ejbest.org

8. Chuchalin, A. I. (2008). Formation of competencies of graduates of basic educational programs. *Higher Education in Russia*, No. 12, pp. 10-19.

A COMPARATIVE EVALUATION OF ESP COURSE IMPLEMENTATION USING THE CIPP MODEL

Gantsetseg Sanjmyatav
(Ph.D) Associate professor
Oyun-Erdene Erdenebileg
Senior Lecturer, TESOL
Mandakh University, Department of Foreign Languages
DOI: 10.5281/zenodo.19827962

ABSTRACT

English for Specific Purposes (ESP) is a form of language instruction designed to equip learners with the linguistic knowledge and skills required for specific academic and professional contexts. The effectiveness of ESP programs depends not only on curriculum content, but also on needs analysis, instructional materials, teaching methodology, implementation quality, and the alignment between intended and achieved outcomes. For this reason, the systematic evaluation of ESP programs has become increasingly important. This study aims to evaluate the implementation of Professional English I and Professional English II courses for accounting and finance students using the CIPP (Context, Input, Process, Product) evaluation model. The participants were students enrolled in two ESP courses at a private university. The ESP-1 evaluation report included 157 second-year accounting students, while the ESP-2 evaluation report covered 117 third-year students majoring in Accounting and Finance. The study employed a document-based comparative evaluation design using descriptive analysis. It sought not only to present the existing evaluation results, but also to examine the pedagogical progression and distinctive emphases of the two courses. The findings reveal high levels of student satisfaction and strong alignment among course objectives, instructional materials, and professional learning outcomes. The integration of digital tools and learner-centered teaching approaches also contributed to positive results. However, the analysis identified oral communication and presentation skills as areas requiring further improvement. Findings indicate that the courses effectively promote the development of professional English competence while also revealing a continued need to enhance communicative competence through future curriculum improvement efforts.

Keywords: CIPP model; course evaluation; Professional English; course implementation; needs analysis.

Introduction

The 1960s marked an important period of change in English language education. As industry expanded, technology advanced, and global connections increased, the demand for English in specialized academic and professional settings grew rapidly. It was within this changing context that English for Specific Purposes (ESP) emerged as a distinct branch of language teaching. Unlike general English instruction, ESP was developed to respond more directly to learners' specific academic, occupational, and professional goals. In this sense, ESP places emphasis not simply on learning English as a general subject, but on using English as a practical tool within a particular field. By linking language instruction to learners' real needs, ESP makes learning more purposeful, relevant, and applicable (Fitria, 2020). Although ESP courses are designed to meet learners' professional needs, evidence of their effective implementation remains limited. Systematic evaluation is therefore necessary to examine the alignment of course objectives, resources, teaching processes, and learning outcomes, beyond student satisfaction alone. Ongoing evaluation also helps monitor program effectiveness and guide necessary improvements. As globalization and specialization continue to grow, the importance of ESP in academic and professional contexts becomes increasingly significant. (Muminova, 2025). Evaluating both student progress and the courses they take has long been a central concern in education. In ESP courses, evaluation is particularly important because these courses are built around specific objectives. The main challenge is to support effective learning by aligning course content with learners' needs, using relevant and authentic materials, applying learner-centered methods, and continuously refining instruction to help students develop the language skills required in their academic or professional settings (Latifaj, 2025). Needs analysis, or needs assessment, has long served as a fundamental component of ESP practice and is expected to remain central to future ESP work. Since emerging in the 1970s, it has developed into a widely recognized framework that has received substantial attention from researchers and practitioners in both ESP and ESL (2023).

Thus, this study adopted Stufflebeam's CIPP model, a widely used framework in English language program evaluation that offers comprehensive insight into both program strengths and areas for improvement.

Literature Review

Despite the growing importance of ESP, studies evaluating ESP courses remain limited. Addressing this gap, Handan Çelik examined tertiary students' end-of-course evaluations of an ESP course offered in the Banking Department of a state university in Turkey. Using a survey design, the study collected both quantitative and qualitative data from 96 students on the ESP instructor, course materials, course content, and suggested areas for improvement (Çelik, 2018).

Mentari Putri Wulan ((March, 2026)) and his co-authors studied the development, trends, applications, and research gaps of the CIPP (Context, Input, Process, Product) Evaluation Model in education. Using a systematic literature review guided by PRISMA 2020 and based on a structured Scopus search, 22 relevant studies were selected through the stages of identification,

screening, eligibility, and inclusion. The findings show that the CIPP model remains a widely applied and adaptable evaluation framework across diverse educational settings, including primary, secondary, higher, and professional education.

In her study (Mičínová, 2023) evaluates the course project assignment in terms of affective outcomes, such as students' perceptions of its benefits and their experience of conducting research, cognitive outcomes related to language and subject knowledge, and behavioural outcomes, including skills development and engagement. Data were obtained through content analysis of students' diaries, project presentations, written reports, and a post-project survey. Similarly, (Mimin Aminah1, 2025) evaluated the implementation of an ESP program for engineering students at a private university in West Java, Indonesia, using the CIPP model. Their findings highlighted the need to align curriculum design, teaching strategies, and resources with learners' needs, while also demonstrating the value of the CIPP model as a comprehensive framework for ESP program evaluation. As noted by Chun-Fu Chen (2009) the CIPP model has been widely used in educational evaluation across different disciplines and contexts. Previous studies have applied it to assess curriculum effectiveness, program relevance, and areas for improvement. For example, Huang (2001) used the model to evaluate a chemical engineering curriculum in Taiwan and found that, although the program generally developed the skills and qualities required by graduates, several course areas needed revision. Wong (2002) applied the CIPP model to a computer studies program in Hong Kong and reported that the program met industry needs and program objectives, while still requiring some operational improvements. Similarly, Umit (2004) used the model to evaluate a Turkish language teaching program in Belarus and found that it only partially met stakeholder needs. Other studies have also employed the CIPP model in evaluating programs in mechanical engineering, banking and insurance, reading instruction, nursing, and coach training, demonstrating its broad applicability in educational settings.

Theoretical Framework: CIPP Model

The CIPP model is a comprehensive framework that evaluates programs through four dimensions—*context, input, process, and product*—and offers the advantage of identifying program goals, implementation quality, and opportunities for improvement simultaneously. This model views evaluation as an ongoing process that supports planning and change within regular institutional programs, rather than as a one-time activity for a single project or study. Unlike traditional models that mainly focus on final outcomes, the CIPP model provides a systematic and flexible approach that supports informed decision-making at every stage of a program (Huang, 2025) In contemporary education, evaluation is no longer seen simply as a way to measure learning outcomes or students' cognitive performance through standardized tests. Rather, it is understood as a broader and more systematic process that considers policy, institutional context, resources, implementation, and program outcomes. This shift reflects the view that educational quality cannot be explained by outcomes alone, but by the interaction of multiple elements within the educational system ((March, 2026)). Tessmer (1993) explains that the four dimensions of the CIPP model—context, input, process, and product—can be used for both formative and summative evaluation. The model serves a formative function when it gathers information for ongoing improvement, and a summative function when it assesses completed activities, interprets overall results, and supports accountability.

Within this framework, ***context evaluation*** examines the environment in which the program operates and considers whether its goals respond to actual needs. It also helps identify unmet needs and missed opportunities. ***Input evaluation*** focuses on planning by reviewing the resources, strategies, and institutional capacity available to achieve the program's goals. In this way, it helps determine the most appropriate course of action. ***Process evaluation*** looks at how the program is implemented and whether activities are carried out effectively and efficiently, while also providing feedback for improvement. Finally, ***product evaluation*** examines the outcomes of the program, including both intended and unintended results, to determine whether its goals were achieved and whether the program should be maintained, revised, or discontinued (Ulumi, 2016).

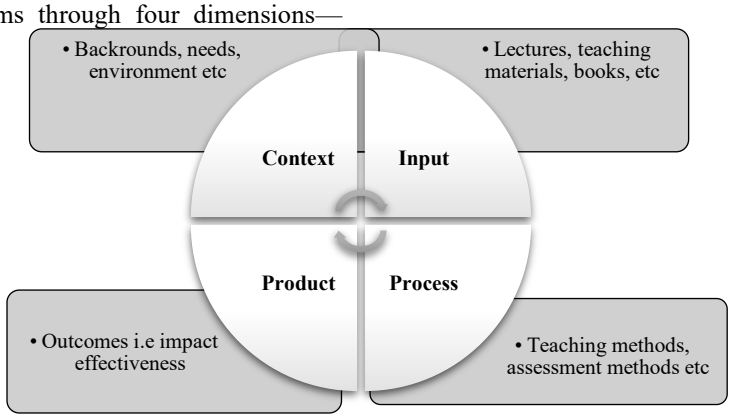


Figure 1 CIPP model

Methodology

This study employed a document-based evaluative analysis using two course implementation reports: one for Professional English I and one for Professional English II. The Professional English I report covered the 2024–2025 academic year, while the Professional English II report covered the 2025–2026 academic year.

The reports included student survey findings, teacher reflections on instructional practices, comments on course strengths and limitations, and comparative evidence from inbound and outbound testing. The survey items from both reports were reorganized and interpreted according to the four dimensions of the CIPP model.

For the purpose of analysis, items related to course goals, clarity, and relevance were categorized under Context. Items concerning instructional materials, assessment tools, resources, and learning platforms were grouped under Input. Items describing implementation, feedback, student guidance, and task alignment were treated as Process indicators. Finally, all items reflecting improvement in student skills, competencies, and measurable progress were analyzed under Product. This analytical framework made it possible to synthesize the two reports into a coherent evaluation structure.

Participants

The participants were students enrolled in the two ESP courses. According to the ESP-1 evaluation report, 157 second-level students with an accounting-related background participated in the survey. According to the ESP-2 evaluation report, 117 third-level students from accounting- and finance-related classes participated in the survey. In both cases, the participants were students studying discipline-specific English within the broader context of accounting and finance education.

Instrument and Data Collection

The main instrument used in the original reports was a course evaluation questionnaire designed to assess students' perceptions of course implementation and learning outcomes. The questionnaire items addressed such areas as clarity of learning expectations, alignment of content with course objectives, appropriateness of instructional materials, usefulness of digital learning tools, clarity of assessment, feedback, and perceived improvement in academic and professional skills. In addition to the quantitative questionnaire data, the reports also included qualitative comments from students and teachers, as well as summary evidence from inbound-outbound test performance.

Analytical Framework

For the purposes of this study, the original survey items from the two reports were analytically reclassified according to the four dimensions of the CIPP model. Items related to the clarity, relevance, and alignment of learning goals were classified under Context. Items concerning instructional resources, textbooks, assessment rubrics, and digital learning support were categorized as Input. Items focusing on feedback, task guidance, and implementation-related instructional processes were grouped under Process. Finally, items reflecting students' perceived improvement in knowledge, skills, and discipline-related competencies were classified under Product. Because the two original questionnaires were not fully identical, the items were further organized into directly comparable items and course-specific items in order to ensure analytical clarity and avoid forced one-to-one equivalence between non-matching indicators.

Results

The data were analyzed through descriptive comparative analysis. First, the mean percentage scores reported for each survey item were extracted from the two evaluation reports. Second, the items were grouped according to the researcher's CIPP-based classification. Third, conceptually similar items across ESP-1 and ESP-2 were compared in order to examine shared implementation strengths and differences. Finally, course-specific items were interpreted separately to identify the distinctive pedagogical emphasis of each course. Qualitative comments from students and teachers were used to support and contextualize the interpretation of the quantitative findings, particularly in relation to the strengths, challenges, and suggested improvements identified in the two reports. To strengthen the analytical rigor of the evaluation, the survey items from ESP-1 and ESP-2 were reorganized according to the four dimensions of the CIPP model, namely Context, Input, Process, and Product. The dimension-level means were calculated based on the researcher's CIPP-based reclassification of the original course evaluation items.

Part A includes only those survey items that were conceptually comparable across ESP-1 and ESP-2. Part B presents course-specific items that appeared in only one of the two evaluation reports. The CIPP categories reflect researcher-led analytical reclassification of the original survey items, while the mean scores were taken from the original course evaluation reports.

Table 1

Comparative Classification of ESP-1 and ESP-2 Course Evaluation Questions According to the CIPP Model with Mean Scores

Part A. Directly Comparable Items

CIPP Dimension	Evaluation Focus	ESP-1 Item	Mean (%)	ESP-2 Item	Mean (%)
Context	Clarity of learning expectations	What I was expected to learn in this course was clear to me.	94.06	What I was expected to learn in this course was clear to me.	93.70
Context	Alignment of content with course objectives	The content of each topic was aligned with the overall objectives of the course.	94.48	The content of each topic was aligned with the overall objectives of the course.	96.00
Input	Integration of theory with learning activities	Theoretical instruction was well connected with independent work.	92.78	Theoretical understanding was well connected with seminar, laboratory, or practical work.	92.00
Input	Clarity of assessment methods and rubrics	The assessment methods and rubrics were clear and understandable.	94.06	The assessment methods and rubrics were clear, understandable, and appropriate to the intended learning outcomes.	91.40
Input	Alignment of instructional materials	The main textbook was consistent with the course content.	95.54	The instructional content was consistent with the main textbook and the curriculum.	95.10
Input	Communication of assessment criteria	The assessment criteria were clearly explained at the beginning of the course.	95.12	The assessment criteria were clearly explained at the beginning of the course.	93.00
Input	Usefulness of digital learning support	The E-mandakh online learning system was useful and easy to use for learning.	90.38	The E-mandakh online learning system was useful and easy to use for learning.	91.30
Process	Role of formative assessment and feedback	Formative assessment and feedback motivated me to prepare for and complete subsequent tasks.	93.63	Formative assessment and feedback motivated me to prepare for and complete subsequent tasks.	90.80
Process	Clarity of task expectations	It was clear what students were expected to do in the course.	94.06	It was clear what students were expected to do in the course.	91.10

As shown in Table 3, both ESP-1 and ESP-2 received consistently high mean scores across the CIPP dimensions, indicating positive student perceptions of course implementation in both stages of the program. Within the Context dimension, both courses were rated highly in terms of clarity of learning expectations and alignment between lesson content and overall course objectives. In particular, the item addressing alignment of content with course objectives received a mean score of 94.48 in ESP-1 and 96.00 in ESP-2, suggesting strong curricular coherence across both courses. In the Input dimension, students in both courses reported high levels of satisfaction with instructional materials, assessment transparency, and digital learning support. The strongest input-related item in both courses was the alignment of instructional materials with curriculum expectations, with mean scores of 95.54 for ESP-1 and 95.10 for ESP-2. Similarly, assessment criteria explained at the beginning of the course were rated positively in both courses, although ESP-1 showed slightly

higher scores than ESP-2 across most comparable input indicators.

Part B: Course-Specific Items

Course	CIPP Dimension	Evaluation Focus	Course-Specific Item	Mean (%)	Interpretation
ESP-1	**Product**	Inquiry and presentation skills	My ability to conduct inquiry, prepare presentations, and present findings improved.	89.53	ESP-1 placed clear emphasis on foundational academic communication and presentation competence.
ESP-1	**Product**	Information-handling skills	My ability to collect, process, and use information improved.	95.02	This was one of the strongest ESP-1 outcomes, highlighting growth in academic information literacy.
ESP-1	**Product**	Professional terminology	My ability to recognize and translate profession-related terminology improved.	93.42	ESP-1 emphasized disciplinary vocabulary development and translation competence.
ESP-1	**Product**	Oral interaction and discourse	My ability to engage in dialogue and express main ideas within a relevant discourse improved.	89.96	ESP-1 included explicit emphasis on basic oral communication and discourse-level expression.
ESP-2	**Process**	Alignment of term papers/assignments with the curriculum	Term papers and assignments were aligned with the course curriculum.	91.60	ESP-2 more explicitly evaluated the curricular coherence of assignments during implementation.
ESP-2	**Product**	Technology use in learning	My ability to use technological advances in learning improved.	92.00	ESP-2 highlighted students' growth in technology-supported learning competence.
ESP-2	**Product**	Accounting-related comprehension and application	My ability to read, understand, and use accounting-related information in everyday practice improved.	92.80	ESP-2 emphasized applied comprehension of discipline-specific content.
ESP-2	**Product**	Profession-related calculation skills	My ability to perform profession-related calculations improved.	91.10	ESP-2 assessed field-specific practical competence beyond general language development.

In terms of the Process dimension, formative feedback and clarity of task expectations were positively evaluated in both courses, indicating that students generally perceived the teaching-learning process as well organized and supportive. However, ESP-1 obtained somewhat higher ratings than ESP-2 on both comparable process indicators. For example, the motivational role of formative assessment and feedback was rated 93.63 in ESP-1 compared with 90.80 in ESP-2, while clarity of task expectations was rated 94.06 in ESP-1 and 91.10 in ESP-2. In addition, ESP-2 included a distinct process-related item on the alignment of independent assignments with the curriculum, which received a mean score of 91.60, reflecting the greater emphasis of the second course on structured independent work.

The Product dimension revealed both shared outcomes and developmental differences between the two courses. In both ESP-1 and ESP-2, teamwork was among the relatively lower-rated outcomes, with mean scores of 89.38 and 90.20, respectively, although both values still indicate generally positive perceptions. At

the same time, the course-specific product items suggest a developmental progression from foundational to applied professional competence. ESP-1 showed strong outcomes in information-handling skills (M = 95.02) and professional terminology development (M = 93.42), whereas ESP-2 showed strong outcomes in accounting-related comprehension and application (M = 92.80), technology-supported learning (M = 92.00), profession-related calculations (M = 91.10), and financial reporting in English (M = 91.60). Taken together, these results suggest that ESP-1 primarily supported the development of foundational academic and disciplinary English competences, while ESP-2 extended these competences into more specialized and profession-oriented applications.

Discussion

The findings suggest that both ESP-1 and ESP-2 were implemented effectively across the main CIPP dimensions, with students reporting positive perceptions of course clarity, curriculum alignment, learning resources, and assessment transparency. This supports earlier studies by Çelik (Çelik, 2018) and Aminah et al. (Mimin Aminah1, 2025), which emphasized the importance of well-structured ESP instruction and the alignment of curriculum, teaching strategies, and resources with learner needs. The results also reveal a clear developmental progression between the two courses, as ESP-1 mainly supported foundational academic and disciplinary English skills, whereas ESP-2 extended these toward more applied professional competencies, consistent with (Mičínová, 2023) emphasis on the cognitive and practical value of ESP tasks. At the same time, lower ratings for teamwork and oral communication in both courses indicate that spoken communicative competence remains underdeveloped, echoing prior CIPP-based studies summarized by (Chen, 2009), (Huang, 2025) which showed that even effective programs often require targeted improvement in specific areas. Overall, the findings confirm that the two courses function as complementary stages within a coherent ESP curriculum and further support the usefulness of the CIPP model as a framework for identifying both strengths and areas for future improvement.

Conclusion

This study employed the CIPP model to evaluate the implementation of ESP-1 and ESP-2 through the four dimensions of context, input, process, and product. The findings demonstrate that both courses were implemented effectively, with evidence of clear instructional goals, appropriate learning resources, well-structured teaching processes, and positive learning outcomes. Overall, the results point to a coherent curriculum design and a generally supportive teaching–learning environment.

From the **context** perspective, both courses were aligned with students' academic and professional needs, indicating that the program was relevant to its intended purpose. In terms of **input**, the findings suggest that the courses were supported by suitable materials, assessment procedures, and digital learning tools, although ESP-2 appeared to involve slightly greater complexity due to its more applied and profession-oriented focus. Regarding **process**, both courses were perceived as organized, clear, and supportive, with positive responses toward instruction, classroom management, and formative feedback. However, ESP-1 received slightly stronger evaluations in some areas, suggesting that students may have found its more foundational content easier to follow than the more demanding structure of ESP-2. From the **product** dimension, the results reveal a clear developmental progression: ESP-1 mainly strengthened foundational academic and disciplinary English skills, whereas ESP-2 extended these into more applied, profession-related competencies.

At the same time, the evaluation identified a common area requiring further improvement across both courses. Speaking performance, teamwork, and interactive communication were comparatively less developed than other outcome areas, indicating the need for more collaborative, discussion-based, and practice-oriented learning activities. Strengthening these aspects would help create a more balanced ESP learning experience and further enhance students' communicative competence in professional contexts.

In conclusion, the findings confirm that ESP-1 and ESP-2 function as complementary stages within a coherent ESP curriculum. More broadly, the study highlights the value of the CIPP model as a systematic and comprehensive framework for evaluating ESP course implementation, identifying strengths and limitations, and informing evidence-based curriculum improvement.

Recommendations

The findings suggest several practical recommendations for improving ESP-1 and ESP-2. First, both courses should place greater emphasis on speaking, teamwork, and interactive communication through more discussion-based, collaborative, and practice-oriented activities. Second, ESP-2 may require additional instructional support, such as clearer guidance and more structured practice, to help students manage its more applied and professionally oriented content. Third, the current developmental progression between ESP-1 and ESP-2 should be maintained so that foundational skills are systematically extended into profession-related applications. Finally, future evaluations should continue to use systematic frameworks such as the CIPP model to support ongoing evidence-based curriculum improvement.

References

1. An Qi Dou 1*, S. H. (2023). Changing visions in ESP development and teaching:Past present, and future. *Frontiers in Psychology*, 1-9.

2. Çelik, H. (2018). A closer look into an esp course through students' end-of-course evaluations: a case study . *The journal of teaching english for specific and academic purposes*, 125-139.

3. Chen, C.-F. (2009). A case study in the evaluation of English training courses using a version of the.

4. Fitria, T. N. (2020). Teaching english for specific purposes to the students in english language

teaching. *Journal of English Teaching Adi Buana, Vol. 05 No. 01, April 2020*, 55-57.

5. Huang, S.-H. (2025 оны December). *Evaluating the English for General Purposes (EGP) program at a Taiwanese University: A CIPP (context, input, process, and product) model study.* Science Direct: https://www.sciencedirect.com/science/article/abs/pii/S0149718925001296

6. KEHAL, M. (2024). Needs Analysis: The Cornerstone of Effective ESP Program Development. *Annals of Guelma University for Social and Human Sciences*, 511-530.

7. Latifaj, D. (2025). Addressing challenges of evaluating learners in an ESP course at a tertiary level. *Revista de Lenguas para Fines Específicos 31*, 144-162.

8. Mentari Putri Wulan*, W. D. ((March, 2026)). A Systematic Literature Review on the CIPP Evaluation Model in Education: Examining Its Trends, Applications, and Research Gaps. *Journal of Educational Sciences Vol. 10 No. 3*, 307-320.

9. Mičínová, I. (2023). *Engaging Students in Doing Research – Evaluation of the ESP Course Project Learning Outcomes.* DOI: https://doi.org/10.5817/CASALC2023-1-1

10. Mimin Aminah1, M. S. (2025). Exploring the Implementation Process of an ESP Program for Engineering Students: A CIPP-Based Evaluation. *Ideas Journal on Language Teaching and Learning,Linguistics and Literature*, 4866 - 4875.

11. Muminova, D. (2025 оны May). TEACHING ENGLISH FOR SPECIFIC PURPOSES (ESP) TO STUDENTS: A COMPREHENSIVE OVERVIEW. *Web of Teachers*, 93-96. Web of Teachers: Interscience Research

12. Ulumi, Ö. G. (2016). EVALUATION OF ENGLISH AS A FOREIGN LANGUAGE PROGRAM - USING CIPP. *European Journal of English Language Teaching*, 115-137.

АДАПТАЦИЯ МЕЖДУНАРОДНЫХ ПРАКТИК УПРАВЛЕНИЯ КАЧЕСТВОМ ОБРАЗОВАНИЯ В ВУЗАХ КАЗАХСТАНА

Абілтаева М.Б.
Казахский национальный педагогический университет им. Абая
Калимолдаева А.К.
старший преподаватель, доктор педагогических наук

ADAPTATION OF INTERNATIONAL QUALITY MANAGEMENT PRACTICES IN HIGHER EDUCATION INSTITUTIONS OF KAZAKHSTAN

Abiltayeva M.
Abai Kazakh National Pedagogical University
Kalimoldayeva A.
Senior Lecturer, Doctor of Pedagogical Sciences
DOI: 10.5281/zenodo.19828008

АННОТАЦИЯ

В статье рассматриваются вопросы адаптации международных практик управления качеством образования в системе высшего образования Республики Казахстан. Актуальность исследования обусловлена необходимостью повышения конкурентоспособности отечественных вузов в условиях глобализации образовательного пространства и усиления требований к обеспечению качества подготовки специалистов. В работе анализируются основные международные модели и стандарты обеспечения качества образования, включая подходы Европейской ассоциации по обеспечению качества в высшем образовании (ENQA), стандарты ESG, а также опыт внедрения систем внутреннего и внешнего контроля качества в зарубежных университетах. Особое внимание уделяется современному состоянию системы управления качеством в казахстанских вузах и выявлению проблем, связанных с адаптацией международных практик. На основе проведённого анализа предложены направления совершенствования механизмов обеспечения качества образования, ориентированные на повышение эффективности образовательного процесса и интеграцию в мировое образовательное пространство.

ABSTRACT

This article examines the adaptation of international quality assurance practices in higher education institutions of the Republic of Kazakhstan. The relevance of the study is driven by the need to enhance the competitiveness of national universities in the context of globalization and increasing demands for the quality of specialist training. The paper analyzes key international models and standards of quality assurance in education, including the approaches of the European Association for Quality Assurance in Higher Education (ENQA), ESG standards, as well as the experience of implementing internal and external quality assurance systems in foreign universities. Particular attention is paid to the current state of quality management systems in Kazakhstani universities and the challenges associated with adapting international practices. Based on the analysis, directions for improving educational quality assurance mechanisms are proposed, aimed at enhancing the effectiveness of the educational process and integrating into the global educational space.

Ключевые слова: управление качеством образования, высшее образование, международные практики, адаптация, Казахстан, обеспечение качества, вузы, ESG, образовательные стандарты.

Keywords: quality management in education, higher education, international practices, adaptation, Kazakhstan, quality assurance, universities, ESG, educational standards.

В современных условиях глобализации и усиления интеграционных процессов в сфере высшего образования особую актуальность приобретает проблема обеспечения и повышения качества образовательных услуг. Университеты разных стран вынуждены адаптироваться к единым международным требованиям, направленным на повышение прозрачности, сопоставимости и конкурентоспособности образовательных систем. В этой связи важную роль играют международные стандарты и модели управления качеством образования, такие как Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), разработанные Европейской ассоциацией по обеспечению качества в высшем образовании (ENQA) [1]. Система ESG представляет собой базовую рамку внутреннего и внешнего обеспечения качества и применяется в странах Европейского пространства высшего образования, а также активно используется за его пределами, включая Казахстан [1]. Внедрение ESG позволяет университетам выстраивать устойчивую систему непрерывного улучшения качества, основанную на принципах прозрачности, подотчётности и ориентированности на студента. В условиях Казахстана данные стандарты стали основой реформирования системы аккредитации и внутреннего контроля качества [3].

Актуальность исследования обусловлена необходимостью модернизации системы высшего образования Республики Казахстан и её интеграции в мировое образовательное пространство. Несмотря на активное внедрение международных подходов к

обеспечению качества, в отечественных вузах сохраняются проблемы, связанные с формализацией процедур оценки качества, недостаточной адаптацией зарубежных моделей к национальному контексту, а также ограниченной эффективностью внутренних систем качества [2].

Следует отметить, что международные практики управления качеством образования включают широкий спектр инструментов: институциональную и программную аккредитацию, внутренние системы обеспечения качества, регулярные процедуры мониторинга образовательных программ, а также участие заинтересованных сторон (студентов, работодателей и академического сообщества) в оценке образовательного процесса [4]. Данные механизмы широко применяются в странах Европы, США и других развитых образовательных системах.

В Казахстане система обеспечения качества высшего образования развивается на основе гармонизации с европейскими стандартами ESG. Аккредитационные агентства и университеты страны постепенно внедряют международные подходы, направленные на повышение качества образовательных программ и управленческих процессов [3]. Однако, как показывают исследования, сохраняются противоречия между формальным внедрением стандартов и их реальным влиянием на качество образования [2].

Таким образом, возникает необходимость научного осмысления процессов адаптации международных практик управления качеством образования к условиям казахстанской системы высшего образования. Это позволит не только повысить эффективность внутренних механизмов обеспечения качества, но и укрепить позиции отечественных вузов в международных рейтингах и образовательном пространстве.

Современная система высшего образования Республики Казахстан функционирует в условиях активной трансформации, связанной с глобализацией образовательного пространства, цифровизацией и усилением международной конкуренции между университетами. В этих условиях особую значимость приобретает проблема обеспечения и управления качеством образования, которое рассматривается как ключевой фактор устойчивого развития вузов и повышения их международной конкурентоспособности.

Одной из основных проблем является необходимость гармонизации национальной системы обеспечения качества образования с международными стандартами, прежде всего с Европейскими стандартами и рекомендациями по обеспечению качества (ESG), разработанными ENQA. Данные стандарты ориентированы на формирование единой системы внутреннего и внешнего контроля качества, основанной на принципах прозрачности, подотчётности и непрерывного улучшения образовательных процессов [1].

Однако, несмотря на активное внедрение международных подходов в систему высшего образования Казахстана, их практическая реализация сталкивается с рядом трудностей. Как отмечают исследователи, в ряде вузов наблюдается формальный характер внедрения систем качества, при котором процедуры аккредитации и внутреннего мониторинга не всегда оказывают реальное влияние на повышение качества образовательного процесса [2].

Таким образом, проблема исследования заключается в противоречии между необходимостью интеграции международных практик управления качеством образования и недостаточной эффективностью их адаптации в условиях национальной системы высшего образования Казахстана.

Вопросы управления качеством образования являются предметом многочисленных научных исследований как зарубежных, так и отечественных авторов. В международной практике значительное внимание уделяется моделям TQM (Total Quality Management), EFQM, PDCA, а также стандартам ISO и ESG, которые формируют основу системного подхода к обеспечению качества в университетах [4].

Согласно исследованиям ENQA, внедрение ESG позволяет университетам формировать устойчивую систему внутреннего обеспечения качества, включающую регулярный мониторинг образовательных программ, участие студентов в оценке качества и развитие культуры качества в академической среде [1]. Аналогичные выводы представлены в работах, посвящённых цифровой трансформации систем качества, где подчеркивается необходимость интеграции аналитических и цифровых инструментов в управление образовательными процессами [3].

Кроме того, в ряде исследований отмечается, что качество высшего образования следует рассматривать как многокомпонентное понятие, включающее не только академические результаты, но и соответствие образовательных программ требованиям рынка труда, уровень компетенций выпускников и степень удовлетворённости заинтересованных сторон [6].

Также значительный вклад в разработку проблемы внесён исследованиями, посвящёнными оценке качества высшего образования через призму результативности выпускников и их дальнейшей профессиональной деятельности. Такой подход позволяет рассматривать качество образования как долгосрочный показатель эффективности образовательной системы [7].

Несмотря на значительное количество научных исследований, посвящённых вопросам управления качеством образования, остаётся ряд нерешённых и недостаточно изученных аспектов.

Во-первых, недостаточно разработаны механизмы **адаптации международных практик (ESG, ENQA, ISO)** к специфическим условиям Казахстана. Большинство исследований ограничивается описанием зарубежного опыта без глубокого анализа возможностей его интеграции в национальную систему высшего образования.

Во-вторых, сохраняется проблема **формализации процедур обеспечения качества**. Во многих

вузах Казахстана внедрение систем внутреннего контроля качества носит административный характер и не всегда связано с реальным улучшением образовательного процесса и учебных результатов студентов [2].

В-третьих, недостаточно исследованы вопросы **цифровизации управления качеством образования**, включая использование аналитических систем, автоматизированного мониторинга и больших данных для оценки эффективности образовательных программ [3].

В-четвёртых, слабо изучена роль **внутренней культуры качества в университетах**, включая участие студентов, преподавателей и работодателей в формировании и оценке образовательных стандартов.

В-пятых, отсутствует единая научно обоснованная модель, которая бы системно объединяла международные практики управления качеством и адаптировала их к условиям высшей школы Казахстана с учётом национальных образовательных стратегий и нормативной базы.

Таким образом, необходимость дальнейшего исследования обусловлена потребностью в разработке комплексного подхода к адаптации международных практик управления качеством образования, учитывающего как глобальные стандарты, так и национальную специфику системы высшего образования Казахстана.

Современная система управления качеством высшего образования базируется на международно признанных подходах, которые формируют единые требования к организации образовательного процесса, его мониторингу и оценке результатов. Наиболее значимой рамочной моделью является ESG (Standards and Guidelines for Quality Assurance in the European Higher Education Area), разработанная Европейской ассоциацией по обеспечению качества в высшем образовании (ENQA) [1]. Согласно ESG, система обеспечения качества включает внутренние и внешние механизмы, направленные на постоянное улучшение образовательных программ, повышение прозрачности и развитие культуры качества в университетах. Данные стандарты широко применяются в странах Европейского пространства высшего образования и служат основой для международной аккредитации [1;8]. Наряду с ESG в международной практике используются модели Total Quality Management (TQM), ориентированные на непрерывное улучшение всех процессов организации и вовлечение всех участников образовательной среды в управление качеством [2]. Также широко применяется модель EFQM, которая позволяет оценивать деятельность университетов по критериям лидерства, стратегии, партнерства и результатов деятельности [4]. Международные стандарты ISO 9000 и ISO 21001 также используются в системе высшего образования как инструмент стандартизации процессов управления качеством и повышения эффективности образовательных услуг [2].

В Казахстане система обеспечения качества высшего образования развивается в направлении гармонизации с международными стандартами. В соответствии с законодательством и образовательной политикой страны, аккредитация вузов осуществляется на основе ESG-подходов, а внутренние системы качества внедряются в рамках институциональных реформ [8;10]. Как показывают исследования, казахстанские вузы активно внедряют системы менеджмента качества, включая ISO 9001, однако эффективность их применения варьируется в зависимости от уровня институциональной зрелости университетов [9]. При этом сохраняется проблема формального характера внедрения отдельных элементов системы качества, что снижает их реальное влияние на образовательный процесс.

Проведённый анализ позволяет сделать следующие выводы:

Во-первых, международные модели управления качеством образования (ESG, TQM, EFQM, ISO) представляют собой комплексные и взаимодополняющие системы, направленные на повышение эффективности и прозрачности образовательных процессов [1;4].

Во-вторых, система высшего образования Казахстана находится в процессе активной интеграции международных стандартов, однако степень их практической реализации остаётся неоднородной [8;10].

Во-третьих, ключевыми проблемами остаются формализация процедур обеспечения качества, недостаточная цифровизация процессов и ограниченная вовлеченность участников образовательного процесса [9].

На основе проведённого анализа предлагаются следующие рекомендации:

– усилить внедрение внутренней системы обеспечения качества в вузах на основе ESG-подхода;

– развивать цифровые платформы мониторинга качества образовательных программ;

– повысить роль студентов и работодателей в оценке качества образования;

– обеспечить переход от формального к результативному подходу в аккредитации;

– адаптировать международные модели с учетом национальных особенностей системы высшего образования Казахстана.

Литература

1. ENQA. Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), 2015. https://www.enqa.eu/esg-standards-and-guidelines-for-quality-assurance-in-the-european-higher-education-area/

2. ISO 9000 Quality Management Systems – Fundamentals and Vocabulary. International Organization for Standardization. https://www.iso.org

3. Brennan J., Shah T. Managing Quality in Higher Education. OECD, 2000.

4. EFQM Excellence Model. European Foundation for Quality Management.

5. Mukhatayev A. et al. Quality Assurance System of Higher Education in Kazakhstan, 2024.

6. ISO 21001:2018 Educational Organizations Management System.

7. Harvey L., Green D. Quality in Higher Education.

8. Закон РК «Об образовании» и система аккредитации вузов.

9. Internal Quality Assurance System in Kazakh universities (ISO 9001 implementation).

10. Bologna Process Kazakhstan QA framework based on ESG.

PHARMACEUTICAL SCIENCES

MEASURING THE SURFACE TENSION OF NASAL MEDICINAL PRODUCTS

Bershadskyi S.
First-year student of Medical Faculty
ORCID: 0009-0009-1217-6410
Klopotiuk V.
First-year student of Medical Faculty
Garlitska N.
PhD, Associate Professor, Department of General Chemistry
ORCID: 0000-0002-8553-7434
I.rbachevsky Ternopil National Medical University, Ukraine
DOI: 10.5281/zenodo.19828048

ABSTRACT

The surface tension of nasal medicinal products affects their rate of evaporation, interaction with a mucous membrane of the respiratory tract and the rate of spreading over biological surfaces. The surface tension of the studied vasoconstrictive nasal pharmaceutical preparations was within the normal range of 37.94 – 42.14 mN/m. A comparative analysis of the obtained data was carried out and the influence of this physicochemical parameter on the distribution of medicinal products over the mucous membrane and their potential pharmacological efficacy was substantiated.

Keywords: Surface tension, nasal drops, mucous membrane, pharmacokinetics.

Introduction. The deterioration of the global environmental situation, the spread of viral infections, and, as a consequence, the increasing incidence of upper respiratory tract diseases lead to a growing demand for nasal medicinal products [1, 7]. Nasal drops are a dosage form intended for local administration that provides a rapid decongestant and vasoconstrictive effect by stimulating α-adrenergic receptors [8, 11]. They reduce hyperemia, swelling of the mucous membrane, and decrease exudation, thereby facilitating nasal breathing in cases of rhinitis. Nasal drops may be vasoconstrictive (0.05 % – 0.1 %), moisturizing (0.65 %), or antiallergic, and are typically supplied in 5–10 mL vials [8].

Nasal drops are one of the simplest and most convenient systems for nasal drug delivery. The main requirements for this dosage form include safety (absence of toxicity), stability of active substances, ease of dosing and compliance with established standards. Nasal drops should be sterile (or have a low level of microbial contamination), possess a pH close to physiological values (5.5 – 6.5) and be isotonic in order to prevent irritation of the mucous membrane [8, 11].

According to the literature, nasal drops deposit human serum albumin in the nostrils more effectively than nasal sprays [3]. Drops spread more widely throughout the nasal cavity and reach the posterior part of the nasal cavity, where mucociliary clearance is more active, which ensures faster elimination of the drug from the cavity [3, 11]. The main drawback of this system is insufficient dosing accuracy; therefore, nasal drops may not be suitable for prescription medications.

Liquid drug delivery systems undergo thorough experimental testing that extends beyond pharmacodynamic and pharmacokinetic studies, including assessments of pH, viscosity, density, stability, isotonicity and other parameters. One parameter that is often overlooked is surface tension at the air–liquid interface. This is more readily understood for oral or parenteral liquid dosage forms, as they rapidly disperse within the body's physiological aqueous environments [5]. However, for nasal preparations, which have significantly greater interaction with air, this parameter may have a considerably greater impact on drug delivery efficiency.

According to the literature, surface tension has become one of the key parameters used to characterize liquid properties in the development of new pharmaceutical dosage forms, particularly for improving drug stability and bioavailability [3, 10]. It has been established that surface tension, as a pharmacological criterion, it is suitable for evaluating drug solubility, pKa, blood–brain barrier penetration, oral in vivo efficacy and drug release [3–4, 6]. Different routes of administration require liquid dosage forms to remain within a specific surface tension range. For example, oral dosage forms typically exhibit a surface tension range of 36.6 to 64.7 mN/m, whereas nasal preparations have a range of 30.3 to 44.9 mN/m [3].

The surface tension of nasal preparations influences their rate of evaporation, interaction with the mucous membrane of the respiratory tract and the rate of spreading over biological surfaces [3, 10]. To minimize irritation, it could be expected that liquid formulations would generally mimic the natural surface tension of the specific site of administration, thereby maximizing interaction. Thus, determining surface tension is appropriate at the stage of development and quality control of nasal drops, as it directly affects their efficacy, safety and ease of use.

The objective of the study was the experimental determination and analysis of the surface tension of liquid nasal drops using a stalagmometer.

Materials and Methods. Five vasoconstrictive nasal drops were selected for the studying of surface tension: "Vibrocil", "Rinazolin", "Farmazolin", "Nazivin", and "Naphthyzin" [9]. The surface tension of the

investigated preparations was measured using a stalagmometer [3, 10]. The number of drops (n_0) formed during the outflow of distilled water (standard liquid) from the stalagmometer and the number of drops (n) for each nasal preparation were determined. Measurements were repeated three times and the average value of the number of drops was calculated. The density (ρ) of the studied solutions was determined using an areometer.The surface tension (σ) of the nasal drops was calculated using a formula (1) and expressed in mN/m:

$$\sigma = \sigma_0 \frac{n_0 \cdot \rho}{n \cdot \rho_0} \quad (1)$$

The surface tension value of distilled water (σ_0) was taken from tabulated data at a temperature of t = 20°C.

Results and Discussion. Vasoconstrictive nasal preparations are a group of medicinal products used locally to reduce swelling of the nasal mucosa and facilitate nasal breathing. They mainly belong to sympathomimetic agents and exert their effect through stimulation of α-adrenergic receptors in the blood vessels of the nasal mucosa, leading to vasoconstriction and a reduction in hyperemia and exudation [1, 7].

The main representatives of this group include derivatives of imidazoline and phenylethylamine, in particular xylometazoline, oxymetazoline, naphazoline and phenylephrine. Some of them, in addition to their vasoconstrictive effect, may exhibit additional properties such as moderate anti-inflammatory, antioxidant or antiallergic activity [7–8]. However, with prolonged or excessive use, the development of tachyphylaxis, drug-induced rhinitis and reduced drug efficacy is possible; therefore, their use should be limited in duration and carefully controlled [8].

For successful absorption of a nasal medicinal product, the active pharmaceutical ingredient must first reach the absorptive barrier. In the nasal cavity, molecules must be absorbed by the epithelial membrane before being eliminated or degraded. In addition, controlling the release profile of the active pharmaceutical ingredient across barriers such as the mucus layer, epithelial layer, and capillary endothelium may be beneficial [6].

Determination the surface tension of nasal drops is a relevant and important physicochemical parameter, especially at the stages of their development and quality control. Surface tension influences the ability of droplets to spread over the nasal mucosa: if this value is high, the droplet poorly wets the nasal surface and may quickly run off before being absorbed. An optimal or lower surface tension ensures a more uniform distribution of nasal pharmaceutical preparations and better contact with the mucous membrane of the nasal cavity.

It was found that all investigated nasal medicinal products had a surface tension at the air–liquid interface lower than a surface tension of the fluid of a mucous membrane of the upper respiratory tract (Table 1). Under normal conditions, the surface tension of nasal mucous secretion is 35–45 mN/m [11]. The investigated surface tension values of nasal drops were as follows: “Vibrocil” – 41.89 mN/m, “Rinazolin” – 37.94 mN/m, “Farmazolin” – 42.14 mN/m, “Nazivin” – 39.70 mN/m, and “Naphthyzin” – 38.35 mN/m. The lower surface tension allows nasal drops to more easily wet the surface of the nasal mucosa and be uniformly adsorbed across it.

The lowest surface tension values were observed for the pharmaceutical preparations “Rinazolin” and “Naphthyzin”. However, this parameter did not exceed the acceptable range. This ensures easier spreading of nasal drops over the surface of the nasal cavity, thereby improving drug distribution and absorption. Nasal medicinal products with lower surface tension may provide potentially higher bioavailability.

Table 1.

Surface tension of the investigated nasal drops

Name of medicinal product	**Active substance (dosage)**	**Pharmacological properties**	**Surface tension, mN/m**
1	2	3	4
Vibrocil	dimetindene maleate (0.25 mg/mL), phenylephrine (2.5 mg/mL)	Phenylephrine belongs to sympathomimetic amines. It is used as a nasal decongestant with a moderate vasoconstrictive effect and selectively stimulates α_1-adrenergic receptors of the cavernous venous tissue of the nasal mucosa. Dimetindene maleate, an H_1-histamine receptor antagonist, exerts an antiallergic effect [9].	41.89
Rinazolin	oxymetazoline (0.5 mg/mL)	Oxymetazoline exerts a sympathomimetic and vasoconstrictive effect, reducing swelling of the nasal mucosa. It constricts blood vessels at the site of application, decreases swelling of the nasal and upper respiratory tract mucosa and reduces nasal discharge. The reduction of nasal mucosal edema promotes the restoration of aeration of the paranasal sinuses and the middle ear cavity, thereby preventing the development of bacterial complications [8].	37. 94

Farmazolin	xylometazoline (1 mg/mL)	Xylometazoline is a sympathomimetic agent that acts on α-adrenergic receptors. Farmazolin causes constriction of nasal blood vessels, reducing swelling of the nasal mucosa and its paranasal sinuses, thereby improving nasal breathing in cases of nasal and sinus congestion. Due to its moisturizing component (sorbitol), the drug helps reduce dryness and irritation of the nasal mucosa [7–8].	42.14
Nazivin	oxymetazoline hydrochloride (0.5 mg/mL)	Oxymetazoline exerts a sympathomimetic and vasoconstrictive effect, relieving swelling of the nasal mucosa. Oxymetazoline also demonstrates antiviral, anti-inflammatory, immunomodulatory, and antioxidant activity [8].	39.70
Naphthyzin	naphazoline (1 mg/mL)	Naphthyzin exerts a pronounced vasoconstrictive effect on peripheral blood vessels through its action on α-adrenergic receptors. When applied to mucous membranes, it reduces edema, hyperemia, and exudation, thereby facilitating nasal breathing in cases of rhinitis. Naphazoline promotes the opening and dilation of the outflow ducts of the paranasal sinuses and Eustachian tubes, improving secretion drainage and preventing bacterial colonization [9].	38.35

According to the experimental results, nasal drops “Farmazolin” and “Vibrocil” exhibit the highest surface tension values. This indicates that these medicinal products are characterized by relatively lower wetting ability, which may limit their uniform distribution over a nasal mucosa and reduce the contact area with the biological surface. The effectiveness of a drug is determined not only by its physicochemical properties but also by its composition, the concentration of active substances and its pharmacodynamic characteristics.

Conclusions. The surface tension of the investigated vasoconstrictive nasal drops ranged within the normal limits of 37.94 – 42.14 mN/m. The lowest values of this parameter were observed for the medicinal products “Rinazolin” and “Naphthyzin”. This contributes to increased bioavailability of active substances. Thus, the determination of surface tension is an important physicochemical parameter that influences drug distribution and its biopharmaceutical effectiveness.

References

1. European Health for all statistical database. URL: http://medstat.gov.ua/ukr/normdoc.html.

2. Han G. E., Priefer R. A. A systematic review of various pK(a) determination techniques *Int. J. Pharm*. Vol. 635. 2023. P. 122783.

3. Han K., Woghiren O. E., Priefer R. Surface tension examination of various liquid oral, nasal, and ophthalmic dosage forms. *Chem Cent J*. No 10. 2016. P. 31.

4. Jaitely V., Karatas A., Florence A. T. Water-immiscible room temperature ionic liquids (RTILs) as drug reservoirs for controlled release. *Int. J. Pharm*. Vol. 354, No (1-2). 2008. P. 168-173.

5. Li Y., Shi J., Zhang X., Ji M., Ni Y., Han R., Li Z., Xiong Y., Tu J., He D., Sun C. Exploration of surface tension measurement methods for pharmaceutical excipients *International Journal of Pharmaceutics.* Vol. 655. 2024. P. 123848.

6. Petereit A. C., Swinney K., Mensch J., Mackie C., Stokbroekx S., Brewster M., Dressman J. B. Prediction of blood-brain barrier penetration of poorly soluble drug candidates using surface activity profiling. *Eur. J. Pharm. Biopharm*. Vol. 75, No 3. 2010. P. 405-410.

7. Pracy R. What use are nose drops? *Arch Dis Child*. Vol. 58, No 12. 1983. P. 946.

8. Stadnytska Ye., Parashchyn Zh. D., Lobur I. P., Fito I.V. Analysis of the internal market of medicines used in diseases of nasal cavity. *Pharmaceutical review*. No 2. 2021. P. 36-43. [Ukrainian]

9. Tabletki.UA URL: https://tabletki.ua/ [Ukrainian]

10. Vargaftik N. B., Volkov B. N., Voljak L. D. International tables of the surface tension of water. *J Phys Chem Ref Data*. No 12. 1983. P. 817–820.

11. Varricchio A., Brunese F., La Mantia I., Ascione E., Ciprandi G. Choosing nasal devices: a dilemma in clinical practice. *Acta Biomed*. Vol. 94, No 1. 2023. P. 2023034.

SOCIAL SCIENCES

THE MEANING OF LIFE IN EASTERN AND WESTERN PHILOSOPHY: A COMPARATIVE ANALYSIS

Valizada K.
Nakhchivan State University, Azerbaijan
ORCID: 0009-0006-8999-3388
DOI: 10.5281/zenodo.19828063

ABSTRACT

The meaning of life is one of the oldest and most persistent questions in the history of philosophy. It appears wherever human beings become reflexive about their existence, suffering, mortality, freedom, duty, happiness, and ultimate destiny. Yet the question has not been posed or answered in a uniform way. In Western philosophy, the problem has often been framed through metaphysics, theology, ethics, rationality, individuality, and existential freedom. In Eastern philosophy, the same issue has usually been approached through liberation, harmony, non-attachment, self-cultivation, and integration with a larger cosmic or relational order. This article offers a comparative philosophical analysis of the meaning of life in major Eastern and Western traditions, with particular attention to Greek philosophy, Christian thought, modern existentialism, Hinduism, Buddhism, Confucianism, and Daoism. The study adopts a qualitative, hermeneutic, and comparative methodology grounded in primary philosophical texts and contemporary scholarly interpretations. The central argument of the article is that Western and Eastern philosophies do not merely provide competing answers; rather, they represent different existential grammars for articulating the human search for significance. Western traditions often treat meaning as a matter of truth, purpose, vocation, autonomy, or value-creation, whereas Eastern traditions frequently view it as realization, awakening, alignment, or release from ignorance and attachment. Despite substantial differences concerning selfhood, suffering, transcendence, and normativity, both traditions converge in affirming that a meaningful life requires ethical transformation, disciplined reflection, and a movement beyond purely material existence. The article concludes that a contemporary global philosophy of life's meaning can benefit from integrating Western concerns for personhood, responsibility, and freedom with Eastern insights into interdependence, self-transcendence, and spiritual practice.

Keywords: meaning of life, existentialism, Buddhism, Hinduism, Daoism, ethics, selfhood.

1. Introduction

The question of the meaning of life is not simply a philosophical puzzle among others. It is a boundary-question: a question that arises when human existence turns back upon itself and asks not merely how to live, but why life matters at all. Unlike technical philosophical problems, it cannot be confined to a single subfield. It touches metaphysics because it asks what kind of world we inhabit; ethics because it asks how we ought to live; philosophical anthropology because it asks what a human being is; theology because it often raises the issue of divine purpose; and existential philosophy because it confronts finitude, anxiety, freedom, and death (Cottingham, 2003; Metz, 2013). For that reason, any serious inquiry into the meaning of life inevitably becomes interdisciplinary even within philosophy itself.

The universality of the question, however, does not imply uniformity in the answers. Civilizations have developed distinct conceptual languages for understanding what makes human existence worthwhile, purposeful, or spiritually significant. In Western philosophy, classical Greek thought framed the question in relation to the good life, virtue, reason, and the telos of human nature. Medieval Christian thought interpreted life in relation to God, salvation, and eternal destiny. Modern philosophy complicated these older frameworks by foregrounding subjectivity, autonomy, skepticism, and the collapse of inherited metaphysical certainties. In Nietzsche, Kierkegaard, Heidegger, Sartre, Camus, and other modern thinkers, the question of meaning becomes inseparable from crisis: the crisis of authority, the crisis of value, and the crisis of the self (Nietzsche, 1974; Sartre, 2007; Camus, 1955; Heidegger, 1962).

Eastern philosophies, by contrast, have often approached meaning less as an abstract speculative question and more as a practical and transformative one. In Hindu thought, the meaning of life is bound up with dharma, karma, and moksha; in Buddhism, the human problem is interpreted primarily through suffering, impermanence, and the path to enlightenment; in Confucianism, meaningful existence is realized through ethical relation, ritual propriety, and social harmony; and in Daoism, the meaningful life is one aligned with the Dao and liberated from artificial striving (Radhakrishnan, 1999; Rahula, 1974; Ames & Rosemont, 1998; Laozi, 2003). These traditions do not always ask "What is the meaning of life?" in the same discursive form found in much of modern Western philosophy. Yet they certainly address the deeper substance of the question by asking how one ought to live, what ultimately matters, how suffering should be understood, and how the self relates to reality.

The distinction between Eastern and Western philosophy must be handled carefully. It can easily become simplistic if treated as a rigid binary. Neither "East" nor "West" is philosophically homogeneous. Greek Stoicism differs from Christian Augustinianism; Hindu Vedanta differs from early Buddhism; Confucianism differs from Daoism; existentialism differs from Aristotelian virtue ethics. Moreover, cross-cultural influence,

internal diversity, and historical transformation complicate any clean division (Nakamura, 1992; Smart, 1998). Nevertheless, the distinction remains analytically useful insofar as it helps illuminate recurring contrasts in philosophical orientation: self versus relation, reason versus contemplation, transcendence versus immanence, autonomy versus harmony, and metaphysical purpose versus experiential awakening.

This article argues that the contrast between Eastern and Western philosophy is most illuminating when it is treated not as an opposition between mutually exclusive doctrines but as an encounter between different ways of articulating existential significance. Western traditions often ask what gives life purpose, worth, or justification. Eastern traditions often ask how ignorance, attachment, disordered desire, or disharmony obscure reality and how a transformed mode of being can be attained. In the former, meaning may be something to discover, justify, or create. In the latter, it may be something to realize, embody, or awaken to. These are not identical projects, but neither are they wholly alien to one another.

The relevance of this inquiry is especially acute in contemporary society. Technological acceleration, consumer culture, political fragmentation, loneliness, ecological anxiety, and the weakening of traditional moral frameworks have intensified the human search for orientation. Modern individuals often enjoy unprecedented freedom while also experiencing deep uncertainty about what constitutes a worthwhile life. At the same time, globalization has brought philosophical traditions into closer contact, making comparative philosophy more than a scholarly exercise: it has become a practical necessity for any serious reflection on humanity's common future (Taylor, 1989; Frankl, 2006). Under these conditions, the question of meaning can no longer be addressed solely within the horizon of one civilizational framework.

The purpose of this study is therefore threefold. First, it aims to reconstruct the major ways in which the meaning of life has been understood in selected Eastern and Western traditions. Second, it seeks to identify convergences and divergences in their conceptions of selfhood, suffering, morality, transcendence, and fulfillment. Third, it proposes that a more adequate contemporary account of life's meaning can emerge through a comparative synthesis that preserves the strengths of both traditions without erasing their differences. The article does not claim that all traditions say the same thing in different words. On the contrary, its central premise is that their differences are philosophically substantive. Yet these differences can be intellectually fruitful rather than divisive.

The main research question guiding the study is: **How do Eastern and Western philosophical traditions conceptualize the meaning of life, and what can a comparative analysis contribute to a contemporary understanding of meaningful human existence?** The subsidiary questions are: What role does selfhood play in each tradition? Is meaning objective, subjective, relational, or transcendent? How is suffering interpreted? What is the relation between ethics and meaning? And finally, can a cross-cultural framework illuminate the search for meaning in an age marked by existential dislocation?

2. Methodological Orientation

This study employs a qualitative and comparative philosophical method. It is not empirical in the narrow social-scientific sense, nor is it purely historical in the sense of reconstructing doctrines without systematic evaluation. Rather, it combines hermeneutic interpretation, conceptual analysis, and comparative philosophical inquiry.

First, a **hermeneutic approach** is used to interpret major texts and traditions within their own conceptual worlds. Philosophical ideas cannot be detached from the linguistic, metaphysical, and ethical contexts in which they arise. To read Aristotle, the Upanishads, the Buddha, Confucius, or Sartre through a single modern conceptual template would distort their internal logic. Hermeneutics, in the Gadamerian sense, recognizes that interpretation involves both historical situatedness and dialogical engagement between text and reader (Gadamer, 2004). This study therefore attempts to respect the integrity of each tradition while also bringing them into a critical conversation.

Second, a **conceptual comparative method** is employed. The inquiry focuses on a set of recurring philosophical themes: the self, purpose, suffering, liberation, virtue, transcendence, freedom, and ethical responsibility. These themes provide a basis for comparison without forcing traditions into artificial equivalence. For instance, Aristotle's eudaimonia is not identical to Buddhist nirvana, nor is Confucian ren simply comparable to Christian agape. Yet comparing how each tradition frames the good, the self, and ultimate fulfillment can reveal both structural parallels and substantive differences.

Third, the study combines **primary philosophical sources** with **secondary scholarly literature**. Classical texts such as Aristotle's *Nicomachean Ethics*, Augustine's *Confessions*, the *Bhagavad Gita*, the *Upanishads*, the *Dhammapada*, the *Analects*, and the *Dao De Jing* are read alongside modern interpreters and contemporary philosophical discussions of meaning in life (Aristotle, 2009; Augustine, 2006; Radhakrishnan, 1999; Rahula, 1974; Ames & Rosemont, 1998; Laozi, 2003; Metz, 2013). This allows the article to move beyond descriptive comparison toward analytical reconstruction.

Finally, the article adopts a **normative-comparative stance**. It is not satisfied merely to catalogue doctrines. It asks what these traditions can contribute to a broader philosophical understanding of meaning today. Comparative philosophy becomes fruitful when it enables conceptual enlargement: when one tradition makes visible the blind spots of another. Western philosophy can clarify the importance of agency, moral responsibility, individuality, and the search for truth. Eastern philosophy can illuminate interdependence, self-transcendence, contemplative practice, and the critique of ego-centered desire. The comparative task, then, is not to flatten difference but to deepen thought.

3. The Question of Meaning in Western Philosophy

Western philosophy has often framed the meaning of life in relation to metaphysical order, moral purpose, and the destiny of the rational self. Although there is no single Western answer, one can trace a broad movement from objective teleology to theistic purpose and then to modern crises of subjectivity and value.

In **Ancient Greek philosophy**, one of the earliest systematic responses appears in Aristotle. For Aristotle, every being has a function, and the function of a human being is rational activity in accordance with virtue. The good life, therefore, is one of **eudaimonia**, often translated as flourishing, well-being, or living well and doing well (Aristotle, 2009). Eudaimonia is not equivalent to pleasure, wealth, or honor, though these may be instrumentally useful. It is the fulfillment of human nature through excellent activity. What makes Aristotle's account philosophically significant is that meaning is neither radically subjective nor externally imposed; it is rooted in the teleological structure of human existence itself. Human life has significance because humans possess a characteristic end, and the achievement of that end requires ethical cultivation.

This conception of meaning also integrates community and reason. Aristotle does not treat the human person as an isolated chooser. Flourishing occurs within the polis and through habituation in virtue. Courage, justice, temperance, and practical wisdom are not merely private excellences; they orient the individual toward a properly ordered life in relation to others. Meaning, then, is inseparable from ethical and civic formation. At the same time, Aristotle gives a special place to contemplation (*theoria*), suggesting that the highest form of life is one oriented toward intellectual activity and truth. This raises a tension internal to his philosophy: is the meaningful life primarily practical and political, or contemplative and quasi-divine? The tension itself would shape later Western thought.

Plato had already laid the groundwork for linking meaning to transcendence. In the *Republic*, justice in the soul mirrors justice in the city, and the philosopher ascends from the world of becoming to the intelligible realm of the Forms, especially the Form of the Good (Plato, 1992). Meaning here lies not simply in social functionality or even virtue alone, but in participation in a higher ontological order. The sensible world is unstable, whereas the realm of truth is enduring. To live meaningfully is to orient oneself toward what is truly real. Already, then, Western philosophy contains a strong metaphysical tendency: life matters insofar as it is connected to truth, order, and the good beyond mere appearance.

The **Stoics** developed another influential model. Thinkers such as Epictetus, Seneca, and Marcus Aurelius argued that meaning arises from living in accordance with nature and reason. Since much of life lies beyond our control, the wise person seeks inner freedom through disciplined judgment and emotional moderation (Long, 2002; Marcus Aurelius, 2002). Stoicism does not ask us to control the world but to govern our response to it. Its account of meaning is especially relevant because it shifts attention from external success to internal integrity. Human existence becomes meaningful not through possession or outcome, but through rational alignment with cosmic order. In times of instability, this Stoic view has repeatedly resurfaced because it addresses suffering without collapse into nihilism.

With the rise of **Christian philosophy**, the meaning of life is reconfigured in a decisively theological direction. Human beings are no longer understood simply as rational animals ordered to their natural telos, but as creatures made by and for God. In Augustine, the existential depth of this orientation is especially clear. The human heart is restless until it rests in God; worldly goods cannot satisfy the deepest longing of the soul because they are finite and mutable (Augustine, 2006). Meaning here is not self-contained within natural human flourishing. It is grounded in a transcendent source and directed toward salvation. Earthly life is significant because it is a pilgrimage toward divine fulfillment.

Aquinas later systematized this view by synthesizing Aristotle and Christianity. For Aquinas, all beings are ordered toward ends, but the ultimate end of rational creatures is the **beatific vision**, the direct enjoyment of God (Aquinas, 1981). Natural virtues remain important, yet they are not sufficient for humanity's highest fulfillment. The meaning of life thus acquires both a natural and supernatural dimension. One can see how this differs from purely secular teleology: the deepest significance of life lies not only in actualizing human capacities but in participating in divine truth and love. In Christian thought, mortality and suffering are not meaningless because they are interpreted through redemption and eschatological hope.

Yet Christian philosophy also intensifies a tension that persists in Western thought: the relationship between earthly and transcendent meaning. Is life meaningful primarily because of what happens within history—ethical action, love, virtue, justice—or because of its relation to eternity? This tension later becomes acute in modernity, when belief in transcendence weakens.

The **modern period** introduces a profound transformation. As metaphysical and religious certainties are challenged by scientific rationality, individual autonomy, and historical criticism, the question of meaning loses its inherited foundation. The Enlightenment affirms reason, progress, and human dignity, but it also destabilizes traditional teleology. Kant, for example, grounds moral worth not in natural ends or divine union but in rational autonomy and the categorical imperative (Kant, 1998). Human beings possess dignity because they are ends in themselves. While Kant does not frame his project directly as a theory of life's meaning, his ethics has clear implications: a meaningful life is one lived under self-given moral law, guided by duty, freedom, and respect for persons. Meaning becomes more closely linked to moral agency than to cosmic order.

However, the modern world also generates what may be called a **meaning crisis**. Nietzsche's declaration that "God is dead" is not merely a theological statement; it is a diagnosis of cultural and existential disorientation (Nietzsche, 1974). If traditional metaphysical and moral foundations have collapsed, then inherited values no longer command unquestioned legitimacy. Meaning can no longer be passively received. It must either be created, revalued, or else abandoned in favor

of nihilism. Nietzsche's response is not despair but value-creation. The strong individual affirms life, even in its suffering, and becomes the author of new values. Meaning here is no longer grounded in objective cosmic order or divine will; it is the achievement of self-overcoming.

Existentialism radicalizes this modern turn. In **Kierkegaard**, the problem is already present as the question of inwardness, anxiety, and authentic commitment. Meaning is not reducible to objective knowledge because existence must be lived subjectively. Truth becomes "subjectivity" in the existential sense of appropriation rather than mere proposition (Kierkegaard, 1985). Although Kierkegaard remains religious, he transforms faith into an existential leap rather than a socially inherited certainty.

In **Heidegger**, the issue of meaning is tied to Being, temporality, and the structure of human existence (*Dasein*). Human beings are not detached subjects but beings thrown into a world, oriented toward possibilities, and defined by their relation to death (Heidegger, 1962). Meaning arises not from abstract speculation but from authentic engagement with one's finite existence. Death individualizes; it breaks the illusion of anonymous conformity. A meaningful life is one in which the person owns his or her possibilities instead of dissolving into the impersonal "they." Heidegger's contribution is crucial because it shows that meaning is inseparable from temporality. One does not possess meaning as an object; one exists meaningfully or inauthentically.

Sartre takes the existential argument further by insisting that "existence precedes essence" (Sartre, 2007). Human beings are not born with a predetermined nature or purpose. They first exist and then define themselves through choice. This grants radical freedom, but also radical responsibility. If no objective essence dictates what one should become, then meaning must be constructed through action. The danger, however, is bad faith: the attempt to flee freedom by pretending one is determined by role, nature, or circumstance. Meaning in Sartre is not found but made, and it is inseparable from responsibility.

Camus introduces the notion of the absurd. Human beings seek clarity, order, and purpose, yet the universe appears silent and indifferent. The absurd arises from this confrontation between human longing and cosmic indifference (Camus, 1955). Camus refuses both metaphysical consolation and despair. His answer is revolt: to live lucidly, passionately, and defiantly without false hope. Meaning, in this context, is not an objective solution but an existential stance. The absurd person creates dignity through refusal to surrender.

In modern Western thought, therefore, one can observe a dramatic shift. Meaning moves from objective telos, to divine purpose, to moral autonomy, and finally to existential creation under conditions of uncertainty. Yet this development is not simply a story of decline. It also represents an intensification of the human capacity for self-reflection and freedom. What is lost in metaphysical assurance may be gained in authenticity and responsibility. Still, the modern Western question often remains burdened by individualism. Even when community and ethics are acknowledged, the central drama frequently unfolds within the isolated self confronting a mute universe. It is precisely here that Eastern philosophy offers a strikingly different orientation.

4. The Question of Meaning in Eastern Philosophy

Eastern philosophical traditions do not always formulate the "meaning of life" as a standalone abstract problem in the manner common to much of modern Western philosophy. Nevertheless, they address the question in substantive ways by asking what the human predicament is, what causes suffering and disorder, how the self should be understood, and what mode of life leads to liberation, harmony, or wisdom. In many Eastern traditions, meaning is not primarily a matter of explaining existence conceptually; it is a matter of transforming existence practically.

In **Hindu philosophy**, the meaning of life is embedded in a comprehensive cosmological and spiritual framework. Human existence is situated within samsara, the cycle of birth, death, and rebirth, governed by karma, the moral law of action and consequence. Within this framework, life cannot be understood in isolation from cosmic order. The concept of **dharma** plays a central role, referring not only to moral duty but to the sustaining order of reality itself (Radhakrishnan, 1999). To live meaningfully is, in part, to live in accordance with one's dharma.

Yet dharma alone is not the final answer. Hindu thought often presents human life as structured by four goals: dharma (duty/righteousness), artha (material well-being), kama (pleasure/desire), and moksha (liberation). This is philosophically significant because it does not deny the legitimacy of worldly aims, but orders them within a broader spiritual horizon. Pleasure and prosperity are not intrinsically meaningless; they become disordered when detached from righteousness and liberation. The highest meaning of life lies in **moksha**, release from ignorance and bondage, and realization of the unity of the self with ultimate reality.

The **Upanishads** articulate one of the most profound metaphysical visions in world philosophy: the identity or deep unity of Atman (the inner self) and Brahman (ultimate reality) (Olivelle, 1996). Ignorance causes human beings to identify themselves with transient empirical existence. True knowledge is not mere conceptual information but transformative insight into the real nature of self and world. In this sense, meaning is realized through self-knowledge, but the "self" discovered is not the egoic, social, or psychological self familiar in modern individualism. It is a deeper spiritual principle. The implication is radical: human life becomes meaningful not by accumulating external achievements, but by awakening to the underlying reality that one already participates in.

The **Bhagavad Gita** provides a particularly rich synthesis of action, devotion, and knowledge. Arjuna's crisis on the battlefield is existential and moral: how should one act in a world marked by conflict, duty, and death? Krishna's teaching presents several paths—karma yoga (selfless action), jnana yoga (knowledge), and bhakti yoga (devotion)—through which life acquires spiritual significance (Easwaran, 2007). The Gita's importance for the philosophy of meaning lies in

its reconciliation of worldly action with transcendence. One need not abandon the world entirely; rather, one must act without attachment to the fruits of action. Meaning emerges through disciplined participation in duty, purified by detachment and oriented toward the divine.

Buddhism offers a very different yet equally profound response. Where some Hindu schools emphasize an ultimate self, Buddhism famously denies any permanent, independent self through the doctrine of **anatta** (non-self). The Buddha's teaching begins not with metaphysical speculation about purpose but with diagnosis: existence as ordinarily lived is marked by **dukkha**, often translated as suffering, dissatisfaction, or unsatisfactoriness (Rahula, 1974). Birth, aging, illness, death, loss, desire, and impermanence are unavoidable features of existence. Yet Buddhism does not conclude that life is meaningless in a nihilistic sense. Rather, it asks what generates suffering and how it can cease.

The **Four Noble Truths** provide the structure: there is suffering; suffering has a cause, namely craving and ignorance; suffering can cease; and there is a path leading to its cessation. Meaning in Buddhism therefore lies not in discovering a cosmic purpose but in awakening from delusion. The **Eightfold Path**—right view, intention, speech, action, livelihood, effort, mindfulness, and concentration—offers a practical method of ethical and contemplative transformation. Meaning is inseparable from discipline. It is not achieved through possession, status, or metaphysical certainty, but through wisdom and compassion.

The Buddhist critique of attachment has major implications for the philosophy of life's meaning. Much Western thought assumes that meaning requires some stable self who possesses purpose, vocation, or value. Buddhism destabilizes that assumption. If the self is not a fixed substance but an impermanent aggregate, then the search for meaning based on egoic permanence is misguided (Harvey, 2013). Paradoxically, life becomes more meaningful when one ceases clinging to the illusion of an isolated self. Compassion becomes central because the recognition of impermanence and interdependence dissolves rigid boundaries between self and other.

Mahayana Buddhism develops this further through the ideal of the bodhisattva, who renounces final nirvana out of compassion for all sentient beings. Meaning here is not private escape from suffering but solidarity within the suffering world. The bodhisattva ideal challenges individualistic conceptions of fulfillment by insisting that awakening is ethically inseparable from responsibility for others (Garfield, 1995). In this respect, Buddhism's account of meaning is both spiritual and profoundly ethical.

In **Confucianism**, the problem of meaning is framed not through metaphysical liberation from rebirth or the cessation of suffering, but through ethical self-cultivation and harmonious social life. Confucian thought begins from the recognition that human beings are relational by nature. One is always already situated in networks of family, ritual, community, and political order. The meaningful life, therefore, is not one of isolated self-expression but one of properly cultivated personhood within a moral community (Ames & Rosemont, 1998).

The central virtues of **ren** (humaneness or benevolence), **li** (ritual propriety), **yi** (rightness), and **xiao** (filial respect) structure this ethical vision. Meaning does not depend on escaping the world but on learning how to inhabit it rightly. Ritual, in Confucianism, is not empty formalism; it is a practice that shapes character, harmonizes relations, and mediates the individual's place within a larger moral order. The self becomes meaningful through cultivation, not through sheer spontaneity or private authenticity.

Confucianism is often read as social ethics rather than existential philosophy, yet this misses its depth. The Confucian project asks what kind of person one ought to become and how one's life can embody moral excellence in ordinary relations. The junzi, or exemplary person, is not meaningful because of metaphysical knowledge or heroic exceptionality, but because he or she embodies ethical integrity in everyday life. In a world where modern individuals often feel alienated from community, Confucianism offers a powerful reminder that meaning may arise less from self-invention than from sustained participation in morally significant relationships.

Daoism offers a contrasting Eastern perspective. If Confucianism emphasizes order, ritual, and cultivated virtue, Daoism often critiques social artificiality and excessive striving. In the *Dao De Jing* and Zhuangzi, meaning is associated with alignment with the **Dao**, the ineffable way or process underlying reality (Laozi, 2003; Zhuangzi, 2009). Human beings become disordered when they impose rigid categories, forceful ambitions, and artificial norms upon life. The Daoist ideal of **wu wei**—often translated as non-action or effortless action—does not mean passivity. It means acting in accordance with the spontaneous rhythms of reality rather than against them.

Daoism is especially important to comparative philosophy because it challenges the Western tendency to equate meaning with purposeful control or rational mastery. A meaningful life, in Daoist terms, may require less assertion and more receptivity; less domination and more attunement. Zhuangzi's reflections on transformation, relativity, and the limits of human judgment expose the anxiety produced by rigid attachment to fixed distinctions. Meaning is not secured by control over life's contingencies, but by graceful participation in them.

Across these Eastern traditions, one finds significant differences. Hinduism often affirms an ultimate self; Buddhism denies it. Confucianism privileges ethical relation; Daoism often relativizes social convention. Yet a number of common tendencies emerge. First, meaning is frequently tied to **self-transformation** rather than mere external achievement. Second, the self is often viewed as relational, illusory, or spiritually deeper than the everyday ego. Third, suffering or disorder is interpreted as arising from ignorance, attachment, imbalance, or ethical failure. Fourth, meaningful life involves discipline—whether through medi-

tation, ritual, devotion, moral cultivation, or contemplative awareness. Finally, many Eastern traditions resist reducing meaning to individual preference. Meaning is not simply what one chooses; it is what one realizes when one becomes aligned with truth, order, or awakening.

This provides a deep contrast with modern Western existential individualism. Yet the contrast should not be overstated. Eastern philosophies do not eliminate agency, nor do Western philosophies lack spirituality or ethical depth. The important point is that Eastern traditions often begin where modern Western ones struggle to arrive: from the premise that the isolated ego is not the final locus of significance. For that reason, they can offer a different grammar of meaning—one centered less on possession, justification, and self-assertion, and more on transformation, harmony, and release.

5. Comparative Analysis: Selfhood, Suffering, Ethics, and Transcendence

A comparative analysis of Eastern and Western approaches to the meaning of life reveals that their deepest divergences cluster around a few major themes: the nature of the self, the interpretation of suffering, the relation between ethics and fulfillment, and the question of transcendence. These themes do not exhaust the issue, but they provide an illuminating framework.

5.1 Selfhood and the Location of Meaning

Perhaps the most decisive difference concerns the **self**. In much of Western philosophy, the self is the central bearer of meaning. Whether in Aristotle's flourishing individual, Augustine's soul before God, Kant's autonomous moral agent, or Sartre's radically free consciousness, meaning is articulated in relation to the destiny, vocation, integrity, or freedom of the person. Even when Western thought criticizes egoism, it often retains a robust notion of personhood as the locus of responsibility and value (Taylor, 1989; Zahavi, 2005).

Eastern philosophy often approaches the self differently. Hindu thought may affirm a deeper spiritual self beyond the empirical ego, while Buddhism dismantles the idea of a permanent self altogether. Confucianism treats the self as irreducibly relational, constituted through ethical roles and cultivated practices. Daoism loosens rigid identity by emphasizing process, spontaneity, and transformation. In all these cases, the everyday self of acquisitive individualism appears unstable or incomplete.

This difference has enormous implications. If meaning is tied to an autonomous individual self, then life's purpose is likely to be framed in terms of self-realization, choice, vocation, authenticity, or salvation of the person. If the self is relational or illusory, then meaning cannot be adequately grounded in self-assertion. It must instead be sought in harmony, awakening, compassion, or release from egoic attachment. Modern Western societies, with their emphasis on self-expression and personal success, often intensify anxiety precisely because meaning is overburdened by the fragile ego. Eastern traditions suggest that one major source of existential misery lies in this very overinvestment in selfhood.

At the same time, Western philosophy contributes an important corrective. A complete dissolution of personhood can obscure the significance of moral agency, accountability, and individual dignity. One of the strengths of Western thought, especially from Christianity through Kant to existentialism, is its insistence that persons matter irreducibly. Human beings are not merely nodes in a cosmic process; they are bearers of responsibility and worth. Thus, a comparative approach need not choose between egoistic individualism and total depersonalization. It can instead distinguish between **selfhood as responsible personhood** and **egoism as possessive attachment**.

5.2 Suffering and the Search for Meaning

A second major point of comparison concerns **suffering**. Western philosophy has often asked whether suffering negates meaning or can itself become meaningful. In Christian thought, suffering may be interpreted through redemption, sacrifice, and hope. In existentialism, suffering becomes the site where absurdity, anxiety, and freedom are disclosed. In Nietzsche, suffering is not simply an evil to be eliminated; it can be formative, even creative, when affirmed as part of life (Nietzsche, 1974). In Frankl's logotherapy, human beings can endure suffering if they discover meaning through work, love, or attitude toward unavoidable pain (Frankl, 2006).

Eastern philosophy, especially Buddhism, begins more directly from suffering as the basic human predicament. Yet the Buddhist treatment is distinctive. It neither glorifies suffering nor interprets it primarily through sin or redemption. Instead, it diagnoses suffering as structurally linked to craving, ignorance, and impermanence. The solution is not metaphysical consolation but transformation of consciousness. This gives Buddhism a psychological and practical acuity that has made it especially influential in modern global discourse.

The difference is subtle but important. Western traditions often ask how meaning can survive suffering. Buddhism asks how misunderstanding the nature of reality generates suffering in the first place. Thus, Western thought frequently preserves a tragic dimension: suffering may remain even in meaningful life. Eastern thought, by contrast, often treats suffering as something to be comprehended and transcended through spiritual discipline. Yet Buddhism does not imply naive optimism; it is profoundly realistic about impermanence and loss. Its distinctiveness lies in refusing to make meaning dependent on permanence.

This has contemporary relevance. Modern societies often oscillate between hedonism and despair because they interpret suffering as evidence of failure or emptiness. Both Western existentialism and Eastern Buddhism challenge this. The former teaches that meaning may emerge through courageous confrontation with pain; the latter teaches that pain becomes spiritually intelligible when attachment and illusion are understood. Together, they suggest that a meaningful life is not one free from suffering, but one transformed in relation to it.

5.3 Ethics and Meaning

A third major issue concerns the relation between **ethics** and meaning. In both Eastern and Western traditions, a meaningful life is rarely understood as merely pleasurable or materially successful. Yet the reasons differ.

Aristotle ties meaning to virtue because flourishing requires the excellent exercise of human capacities. Christian thought links meaning to love, obedience, and holiness because human life is ordered toward God. Kant grounds meaningful moral existence in duty and rational autonomy. Existentialists, even when rejecting objective morality, insist that choices define human reality and entail responsibility. In all these traditions, ethics is not optional; it is constitutive of meaningfulness.

Eastern thought also insists on the ethical dimension of meaning, but often in a more relational or transformative form. Confucianism makes ethical cultivation the very substance of meaningful life. Buddhism joins wisdom with compassion; enlightenment without ethical conduct is impossible. Hinduism interprets life through dharma as well as liberation. Daoism, though suspicious of artificial morality, still points toward humility, simplicity, and non-domineering ways of being.

One major difference is that Western ethics often emphasizes law, virtue, conscience, or freedom, whereas Eastern ethics often emphasizes harmony, discipline, relation, or compassion. Yet in both traditions, meaning is not reduced to subjective feeling. One may feel fulfilled and yet live badly. This convergence is philosophically crucial in a time when meaning is often psychologized into mere life-satisfaction. The deeper traditions insist that meaningfulness involves a normative dimension: there are better and worse ways of being human.

5.4 Transcendence, Immanence, and Ultimate Reality

The meaning of life also depends on whether reality is understood as containing a transcendent order or whether meaning must be constituted within finite existence. In Western thought, transcendence often takes the form of God, the Good, eternal truth, or moral law. Even secular philosophers frequently inherit this structure by asking whether life has objective value beyond individual preference. The modern crisis of meaning often emerges precisely when this transcendent background becomes uncertain.

Eastern philosophies present several alternatives. Hinduism affirms ultimate reality in Brahman and often interprets life through metaphysical unity. Buddhism avoids many metaphysical assertions yet still points beyond ordinary delusion toward awakening. Confucianism is less overtly metaphysical but embeds human life within Heaven, order, and moral tradition. Daoism emphasizes immanent participation in the Dao rather than transcendence conceived as a separate realm.

This suggests that Eastern traditions often blur the distinction between transcendence and immanence. Ultimate reality is not always "elsewhere"; it may be disclosed in transformed perception, disciplined practice, and attunement to the present. This can be philosophically fruitful for modern thought, which often oscillates between supernaturalism and flat secularism. Eastern philosophy offers models in which life's meaning is neither reducible to worldly utility nor dependent on an external supernatural guarantee. It may be realized through a deepened mode of inhabiting reality itself.

5.5 Objectivity and Subjectivity

A final comparative issue concerns whether meaning is objective or subjective. Many Western debates frame the issue in these terms. Some argue that life is meaningful only if it corresponds to objective goods or divine purpose; others contend that meaning is whatever individuals find deeply fulfilling; hybrid theories hold that subjective attraction must connect with objectively worthwhile activities (Wolf, 2010; Metz, 2013).

Eastern traditions do not always frame the issue this way. Meaning is often neither merely subjective nor externally objective. It is relationally realized through right practice, insight, or harmony. For example, in Buddhism, awakening is not a private invention, yet it is not imposed as an external command. It arises through disciplined realization of reality. Confucian meaning is not just "my preference," nor is it a cold abstraction; it is embodied in ethical relation. This suggests that the objective/subjective dichotomy itself may be too narrow. Meaning may be best understood as **participatory**: something that emerges when persons are rightly related to self, others, nature, and ultimate reality.

6. Discussion: Toward an Integrated Philosophy of Life's Meaning

The comparative analysis conducted above suggests that Eastern and Western philosophies are not simply rival sets of doctrines but different orientations within a larger human search for significance. If this is so, then the most promising contemporary response to the question of life's meaning may not lie in choosing one tradition against the other, but in learning from their mutual illumination.

One major contribution of Western philosophy is its insistence on **personhood, freedom, and responsibility**. The Western tradition, especially in its Greek, Christian, Kantian, and existential forms, refuses to allow the human being to disappear into anonymous cosmic process. It affirms that individuals matter, that choices have moral significance, and that meaning cannot be separated from accountability. This is philosophically indispensable. Any contemporary theory of meaning that ignores dignity, freedom, and moral responsibility risks collapsing into fatalism, quietism, or impersonal holism. In political and ethical life, the Western stress on rights, conscience, and the irreducible worth of persons remains essential.

At the same time, Western philosophy often suffers from excessive **individualization** of meaning. The modern self is frequently imagined as a sovereign chooser who must generate significance from within, often against a background of social fragmentation and metaphysical uncertainty. This can produce creativity, but it also generates anxiety, alienation, and exhaustion. When meaning becomes a private project of self-construction, failure becomes existentially devastating. One is responsible not only for one's choices, but for

the very justification of one's existence. Here Eastern traditions provide an important corrective.

Eastern philosophy reminds us that a meaningful life is not necessarily one built through maximal self-assertion. It may instead require **self-transcendence, discipline, humility, and attunement**. Buddhism teaches that much suffering arises from clinging to the self as a fixed entity. Confucianism shows that meaning is often found in ethical relation rather than private authenticity. Daoism reveals the violence of excessive control and the wisdom of receptivity. Hindu thought opens the possibility that the deepest self is not the acquisitive ego but a spiritual reality obscured by ignorance. These insights are especially significant in an age defined by consumerism, digital performance, and perpetual self-comparison.

A contemporary integrated philosophy of meaning might therefore rest on five principles.

First, meaning should be understood as **more than subjective satisfaction**. Pleasure, success, and preference cannot by themselves ground a meaningful life. Both Eastern and Western traditions converge in treating ethical and spiritual transformation as essential. A meaningful life involves becoming a certain kind of person, not merely feeling a certain way.

Second, meaning should be understood as **participatory rather than purely possessive**. We do not simply "have" meaning as we have an object. Meaning arises through relation—to truth, to others, to moral goods, to nature, to community, and perhaps to ultimate reality. This relational view draws on Confucian, Buddhist, Aristotelian, and Christian elements alike.

Third, meaning requires a balance between **personhood and self-transcendence**. The human being is neither an isolated ego nor a disposable illusion. We are finite persons whose flourishing requires going beyond narcissistic self-enclosure. Western traditions preserve individuality and responsibility; Eastern traditions show how ego-centered attachment distorts existence. A balanced philosophy must affirm both.

Fourth, suffering must be integrated rather than denied. A meaningful life is not one insulated from finitude, loss, and death. Western existentialism teaches courage before absurdity and mortality; Buddhism teaches mindful transformation of suffering through non-attachment and wisdom; Christianity interprets suffering through hope and love; Stoicism cultivates resilient acceptance. These approaches differ, but all reject the fantasy that meaning depends on perfect control.

Fifth, meaning is inseparable from **practice**. This may be the most important lesson from Eastern philosophy for modern intellectual culture. One cannot think one's way into a meaningful life without living differently. Meditation, prayer, ethical discipline, ritual, self-examination, civic virtue, contemplation, and compassionate action are not secondary ornaments to theory. They are constitutive of the meaningful life itself. Aristotle knew this as habituation; Confucius knew it as ritual cultivation; Buddhism knows it as the path; Christianity knows it as spiritual formation. Meaning is existentially enacted, not merely conceptually defined.

Such an integrated framework is particularly valuable under present global conditions. Contemporary societies face not only technological and political crises, but crises of orientation. Many individuals are materially connected yet spiritually fragmented, informed yet unwise, expressive yet lonely. The search for meaning is intensified by secularization, mobility, identity instability, ecological threat, and the weakening of inherited communities. Under such conditions, the comparative study of philosophy is not antiquarian. It becomes a resource for intellectual and ethical renewal.

This does not mean that East and West can be harmonized without remainder. Real differences remain. Buddhism's non-self doctrine cannot simply be collapsed into Christian personalism; Nietzschean value-creation cannot be equated with Confucian ritual ethics; Daoist spontaneity resists the structure of Kantian duty. Yet comparison need not eliminate disagreement to be fruitful. On the contrary, disagreement often reveals hidden assumptions. Western thought learns from Eastern philosophy that the self is less stable, less sovereign, and less central than it often assumes. Eastern philosophy may, in dialogue with Western thought, more explicitly confront issues of rights, political individuality, and the moral importance of irreducible personhood. Mutual criticism becomes a form of philosophical enrichment.

In this sense, the meaning of life may be best conceived neither as a single final answer nor as a merely subjective preference, but as a field of existential orientation structured by enduring human concerns: truth, suffering, relation, virtue, mortality, freedom, and transcendence. Different traditions illuminate these concerns in different registers. The task of comparative philosophy is not to produce a lowest common denominator, but to expand our capacity to think and live meaningfully.

7. Conclusion

The question of the meaning of life continues to endure because it names something constitutive of human existence: our inability to live without some orientation toward what matters ultimately. Eastern and Western philosophical traditions have developed distinct but overlapping responses to this question. Western philosophy, from Greek virtue ethics through Christian theology to modern existentialism, has tended to frame meaning in terms of telos, salvation, moral autonomy, authenticity, and value-creation. Eastern philosophy, in its Hindu, Buddhist, Confucian, and Daoist forms, has often approached meaning through liberation, harmony, self-cultivation, non-attachment, and alignment with a larger order.

The differences are substantial. Western traditions often foreground personhood, rationality, and the individual's relation to truth or God. Eastern traditions frequently decenter the ego and locate significance in relation, awakening, or ontological harmony. Western philosophy often asks what gives life purpose; Eastern philosophy often asks what obstructs wisdom and how one should live to overcome suffering or disorder. Yet the traditions also converge in crucial ways. Both reject the reduction of life to material success or hedonistic

pleasure. Both see ethical transformation as indispensable. Both insist that meaningful existence demands disciplined reflection and a movement beyond superficial immediacy.

The comparative analysis undertaken here suggests that neither tradition alone exhausts the question. Western philosophy preserves the indispensable values of freedom, dignity, and responsibility, but often overburdens the isolated self. Eastern philosophy offers profound insight into interdependence, self-transcendence, and spiritual practice, but may require supplementation where questions of individuality and moral agency are concerned. A contemporary philosophy of life's meaning can therefore benefit from an integrative approach: one that affirms personhood without egoism, ethics without moralism, transcendence without escapism, and spiritual depth without loss of responsibility.

Ultimately, the meaning of life may not be reducible to a single formula. It may consist in the ongoing work of becoming truthful, compassionate, responsible, and awakened within a finite and fragile world. If so, the comparative dialogue between East and West does not merely provide academic knowledge. It expands the horizon within which human beings can understand themselves and live more wisely.

References

1. Ames, R. T., & Rosemont, H. (1998). *The analects of Confucius: A philosophical translation*. Ballantine Books.
2. Aquinas, T. (1981). *Summa theologica* (Fathers of the English Dominican Province, Trans.). Christian Classics.
3. Aristotle. (2009). *Nicomachean ethics* (W. D. Ross, Trans.). Oxford University Press.
4. Augustine. (2006). *Confessions* (H. Chadwick, Trans.). Oxford University Press.
5. Baumeister, R. F. (1991). *Meanings of life*. Guilford Press.
6. Blackburn, S. (2001). *Being good: A short introduction to ethics*. Oxford University Press.
7. Camus, A. (1955). *The myth of Sisyphus and other essays* (J. O'Brien, Trans.). Penguin.
8. Cooper, J. M. (1985). *Reason and human good in Aristotle*. Harvard University Press.
9. Cottingham, J. (2003). *On the meaning of life*. Routledge.
10. Craig, W. L. (2008). *Reasonable faith: Christian truth and apologetics*. Crossway.
11. Dreyfus, H. L., & Wrathall, M. A. (Eds.). (2005). *A companion to Heidegger*. Blackwell.
12. Easwaran, E. (2007). *The Bhagavad Gita* (2nd ᵉd.). Nilgiri Press.
13. Eliade, M. (1958). *Yoga: Immortality and freedom*. Princeton University Press.
14. Frankl, V. E. (2006). *Man's search for meaning*. Beacon Press.
15. Gadamer, H.-G. (2004). *Truth and method* (2nd ʳev. ed., J. Weinsheimer & D. G. Marshall, Trans.). Continuum.
16. Garfield, J. L. (1995). *The fundamental wisdom of the middle way: Nagarjuna's Mulamadhyamakakarika*. Oxford University Press.
17. Hadot, P. (1995). *Philosophy as a way of life* (M. Chase, Trans.). Blackwell.
18. Harvey, P. (2013). *An introduction to Buddhism: Teachings, history and practices* (2nd ᵉd.). Cambridge University Press.
19. Heidegger, M. (1962). *Being and time* (J. Macquarrie & E. Robinson, Trans.). Harper & Row.
20. Hick, J. (1976). *Death and eternal life*. Harper & Row.
21. Inwood, B. (Ed.). (2003). *The Cambridge companion to the Stoics*. Cambridge University Press.
22. James, W. (2000). *The varieties of religious experience*. Modern Library.
23. Kant, I. (1998). *Groundwork of the metaphysics of morals* (M. Gregor, Trans.). Cambridge University Press.
24. Kierkegaard, S. (1985). *Fear and trembling/Repetition* (H. V. Hong & E. H. Hong, Trans.). Princeton University Press.
25. Koller, J. M. (2007). *Asian philosophies* (5th ᵉd.). Pearson.
26. Laozi. (2003). *Dao De Jing: A philosophical translation* (R. T. Ames & D. L. Hall, Trans.). Ballantine Books.
27. Long, A. A. (2002). *Epictetus: A Stoic and Socratic guide to life*. Oxford University Press.
28. MacIntyre, A. (1984). *After virtue* (2nd ᵉd.). University of Notre Dame Press.
29. Marcus Aurelius. (2002). *Meditations* (G. Hays, Trans.). Modern Library.
30. Marino, G. D. (Ed.). (2004). *Basic writings of existentialism*. Modern Library.
31. Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review, 98*(2), 224–253.
32. Metz, T. (2013). *Meaning in life: An analytic study*. Oxford University Press.
33. Nagel, T. (1986). *The view from nowhere*. Oxford University Press.
34. Nakamura, H. (1992). *A comparative history of ideas*. Princeton University Press.
35. Nietzsche, F. (1974). *The gay science* (W. Kaufmann, Trans.). Vintage.
36. Nozick, R. (1989). *The examined life: Philosophical meditations*. Simon & Schuster.
37. Olivelle, P. (Trans.). (1996). *Upanishads*. Oxford University Press.
38. Parfit, D. (1984). *Reasons and persons*. Oxford University Press.
39. Plato. (1992). *Republic* (G. M. A. Grube, Trans., rev. C. D. C. Reeve). Hackett.
40. Rahula, W. (1974). *What the Buddha taught*. Grove Press.
41. Radhakrishnan, S. (1999). *Indian philosophy* (Vols. 1–2). Oxford University Press.
42. Russell, B. (2004). *The conquest of happiness*. Routledge.
43. Sartre, J.-P. (2007). *Existentialism is a humanism* (C. Macomber, Trans.). Yale University Press.
44. Schopenhauer, A. (1969). *The world as will and representation* (E. F. J. Payne, Trans.). Dover.
45. Smart, N. (1998). *World philosophies*. Routledge.

46. Smith, H. (1991). *The world's religions*. HarperOne.

47. Solomon, R. C. (2005). *Existentialism* (2nd ed.). Oxford University Press.

48. Taylor, C. (1989). *Sources of the self: The making of the modern identity*. Harvard University Press.

49. Tolstoy, L. (2000). *A confession* (D. Patterson, Trans.). Norton.

50. Van Norden, B. W. (2011). *Introduction to classical Chinese philosophy*. Hackett.

51. Williams, B. (1973). *Problems of the self*. Cambridge University Press.

52. Wolf, S. (2010). *Meaning in life and why it matters*. Princeton University Press.

53. Wong, D. B. (2006). *Natural moralities: A defense of pluralistic relativism*. Oxford University Press.

54. Zahavi, D. (2005). *Subjectivity and selfhood: Investigating the first-person perspective*. MIT Press.

55. Zhuangzi. (2009). *Zhuangzi: The essential writings* (B. Watson, Trans.). Columbia University Press.

TRENDS IN THE STUDY OF SMART HEALTHCARE SYSTEMS FOR THE ELDERLY IN CHINA: A BIBLIOMETRIC ANALYSIS

Ying Chen
PhD in Social Services (Social Work and Counseling)
Department of Social Administration and Justice, Faculty of Arts and Social Science,
University of Malaya,
Kuala Lumpur, Malaysia
ORCID: 0009-0000-0374-7319
DOI: 10.5281/zenodo.19828075

ABSTRACT

As China's population continues to age, the need for innovative solutions in elderly care will become increasingly critical. In response to this demographic shift, smart healthcare systems are developed to support independent living and improve the quality of life for older adults. The study maps the rapid evolution of smart-healthcare research for China's elderly by analyzing 113 English-language records retrieved from Web of Science between 1 January 2020 and 1 July 2025. The corpus spans 2000-2025 and shows a robust annual growth rate of 22.1 %, reflecting sustained investment in response to China's ageing society. Using the Bibliometrix package in R, we extracted 574 authors from 77 sources, yielding an average document age of 2.15 years and 7.15 citations per paper. The findings indicate that research are concentrated on the integration of advanced technologies in healthcare, the usability and acceptance of digital solutions among older adults, and the impact of policy initiatives on system implementation.

Keywords: Smart Healthcare Systems; Bibliometric Analysis; Elderly Care; R Studio.

1. Introduction

China is currently experiencing profound demographic transformations characterized by an unprecedented increase in the elderly population. This shift is the result of various interrelated factors, including decreased fertility rates, improved life expectancy, and long-standing socio-economic changes. By the year 2050, it is projected that approximately 35% of China's population will be aged 65 and older, intensifying the challenges associated with an aging society and requiring adaptive strategies in healthcare and public policy (Wang et al., 2022).

The demographic transition in China has occurred rapidly, particularly following the implementation of the one-child policy in 1979, which significantly reduced birth rates (Hu, 2023). Consequently, the proportion of the elderly, defined as those aged 60 and older, has increased significantly; in 2000, this demographic segment composed 10% of the population, a figure that continues to rise (Ma et al., 2023). Additionally, improvements in healthcare, economic growth, and enhanced living standards have led to increased life expectancy, further exacerbating this demographic phenomenon (Luo et al., 2021). The aging population may lead to higher costs associated with healthcare services and social security, necessitating substantial adjustments in economic planning and resource allocation (Li, 2023).

China's demographic transition underscores the urgency of addressing the needs of an aging population through innovative and sustainable approaches in healthcare, economic policy, and social support systems. Analyzing the implications of these demographic shifts will be crucial to understanding future societal and economic trends in the country. As China's population ages, innovative solutions in elderly care have become crucial to address the complex challenges posed by this demographic shift. With projections indicating that by 2050, nearly 35% of China's population will be aged 65 and older, the urgency for effective elderly care systems is evident (Wang et al., 2022).

The elderly population in China can potentially benefit from the application of smart healthcare systems. Smart healthcare aims to intelligently manage healthcare needs and ensure timely access to preventive and curative services through advanced technologies such as system integration, interconnection, and intelligent processing. This reflects significant advancements in information technology development within the healthcare sector. With the goal of promoting a healthy life for all, smart healthcare integrates technologies like the Internet of Things (IoT) and artificial intelligence (AI) into the medical field to provide enhanced medical and health services. However, elderly individuals often encounter challenges in adopting smart healthcare systems, which may include difficulties in using smart terminals. Poor understanding of smart healthcare implementation can hinder realization of its benefits for older adults and could even lead to adverse outcomes. While researchers have investigated the application of smart healthcare systems for the elderly, the literature is often fragmented, lacking a comprehensive understanding of how older adults benefit from these systems. Therefore, a thorough study using bibliometric analysis is necessary to analyze and elaborate on the application of smart healthcare in the elderly population, as highlighted in recent research (Zhu et al., 2023, Hung, 2022).

Bibliometrics is a valuable scientific tool that is widely used in various fields, including biomedicine. In recent years, R Studio and Biblioshiny have emerged as popular platforms for conducting bibliometric analysis (Ho et al., 2022). R Studio is a versatile and user-friendly programming environment that allows for customized bibliometric analyses using various R packages. Biblioshiny, on the other hand, is a web-based application built on R Shiny that provides an intuitive interface for visualizing bibliometric data. It enables users to easily construct interactive visualizations such

as co-authorship networks, citation maps, and keyword co-occurrence diagrams, without requiring extensive technical expertise (Ho et al., 2022). Biblioshiny is particularly advantageous for its simplicity and ease of use, making it accessible to researchers who may not be familiar with more complex software tools. It allows users to extract key scientific insights from the literature, generate various visual representations, and identify emerging trends through its built-in analysis tools.

Despite the growing body of research on smart healthcare for older adults, there is still a notable gap in the application of advanced bibliometric and visual analysis tools within this domain (Hu et al., 2023). Therefore, this study leverages R Studio and Biblioshiny to conduct comprehensive bibliometric and visual analyses of the existing research. This approach not only provides a clear understanding of the current state of research but also identifies prevailing topics of interest and predicts future trends in the field of smart healthcare systems for the elderly, offering valuable guidance for future investigations from a China perspective.

2. Methodology

2.1. Search Strategy and Search Flow

To conduct a bibliometric analysis of Smart Healthcare Systems for the Elderly in China, we sourced our data from the Web of Science Core Collection (WOS-CC). Our search strategy was intentionally broad to capture the multifaceted nature of this research area. Data collection was completed in July 2025, and the specific search parameters are detailed in Appendix A. The search query can be summarized as: (TS = (smart health systems)) AND TS = ("old adults" OR "old man" OR "the aged" OR "the elderly" OR "elderly" OR "senior* " OR "older people" OR "old people" OR "old person" OR "older person" OR "older adult*") AND (CU = China). This search spanned the period from January 1, 2020, to July 1, 2025, and was not limited by publication date, adhering to the indexing criteria of the Web of Science database (Fig.1).

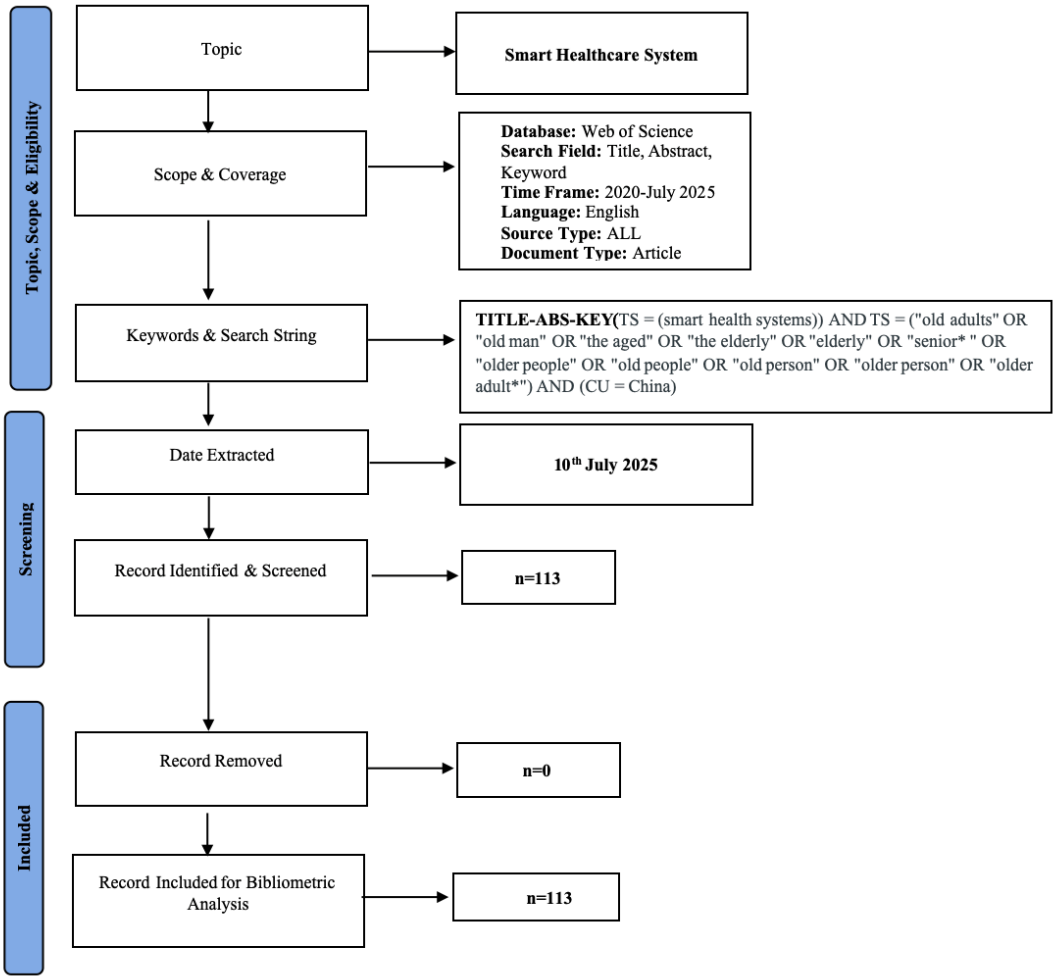

Topic, Scope & Eligibility
Topic
Smart Healthcare System
Scope & Coverage
Database: Web of Science
Search Field: Title, Abstract, Keyword
Time Frame: 2020-July 2025
Language: English
Source Type: ALL
Document Type: Article
Keywords & Search String
TITLE-ABS-KEY(TS = (smart health systems)) AND TS = ("old adults" OR "old man" OR "the aged" OR "the elderly" OR "elderly" OR "senior* " OR "older people" OR "old people" OR "old person" OR "older person" OR "older adult*") AND (CU = China)
Screening
Date Extracted
10th July 2025
Record Identified & Screened
n=113
Included
Record Removed
n=0
Record Included for Bibliometric Analysis
n=113

Figure 1. Literature selection flowchart

2.2 Data Analysis with Bibliometrix R Package

In this study, the Bibliometrix R package, available at http://www.bibliometrix.org, was employed to perform a comprehensive bibliometric analysis within the RStudio-2025.05.1-513 programming environment. The analysis was further refined using the Biblioshiny tool, which facilitated an in-depth exploration of publication trends, institutional contributions, author contributions, journal analysis, and keyword analysis. This approach allowed for a detailed understanding of the dynamics within the field of smart healthcare systems for the elderly in China.

3. Results

3.1. Summary of the Papers

According to the 113 papers published from 2000 to July 1st, 2025, it highlights a robust growth in smart healthcare systems research for the elderly in China, with an annual growth rate of 22.1%. It encompasses

113 documents from 77 sources, averaging 2.15 years in document age and 7.15 citations per document (Appendix A). The analysis identified 574 authors, with a notable international co-authorship rate of 37.17%.

3.2 Annual Publication Trends

From the analysis of 113 publications—spanning from 2020 to July 1, 2025— there is a notable surge in research dedicated to smart healthcare systems for the elderly in China (Fig. 2). Conducted using data from the Web of Science Core Collection Database, this bibliometric analysis reveals an annual growth rate of 22.1%. This rate underscores a consistent and significant expansion in the academic output concerning smart healthcare solutions tailored for China's aging population over the specified period.

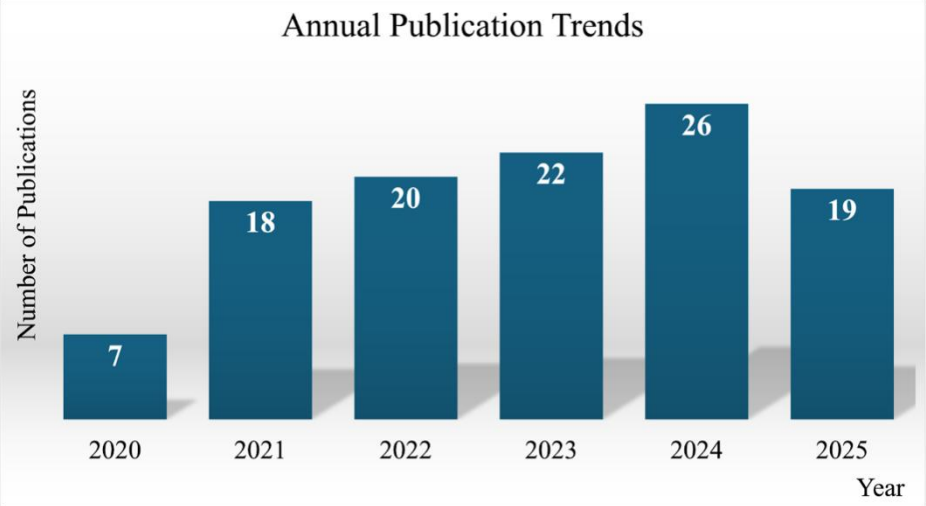


Figure 2. Annual Publication Trends(2020.01-2025.07)

3.3 Institution Contributions

The Figure illustrates the contributions of the top 15 institutions in the research domain of smart healthcare systems for the elderly in China (Fig. 3). The chart reveals a significant involvement of Chinese institutions, highlighting the country's commitment to advancing elderly care through technology. Fudan University leads the pack with 11 publications, indicating its prominent role in driving research and innovation in this field。Chongqing Medical University and Central South University follow closely, each contributing 9 publications, underscoring their substantial efforts in smart healthcare research。Tsinghua University and Dalian University of Technology also make notable contributions with 8 publications each, demonstrating their active engagement in developing smart healthcare solutions。

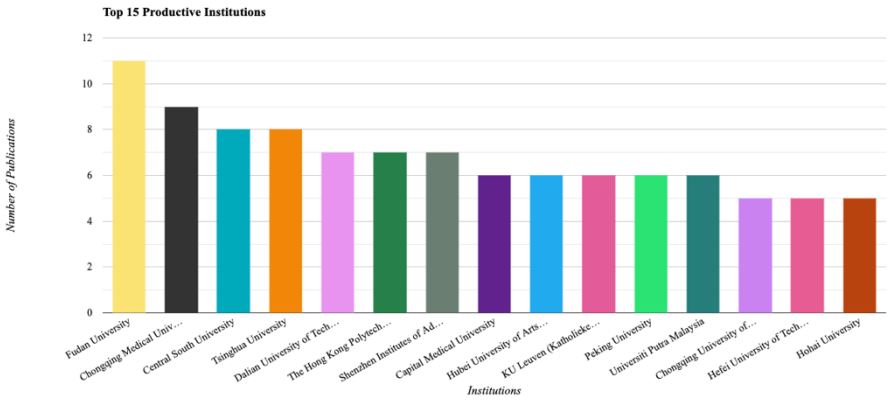


Figure 3. Top 15 Productive Institutions

3.4 Author Contributions

In the realm of smart healthcare for the elderly, a substantial number of authors have contributed to the field. Specifically, 574 authors have participated in this research area. Among these, a notable subset of 17 authors have demonstrated a higher level of engagement by contributing at least two articles each (Fig. 4). This active participation indicates a dedicated group of researchers who are driving the development of smart healthcare solutions for the elderly population. Their collective efforts are crucial in shaping the discourse and advancing knowledge within this specialized field.

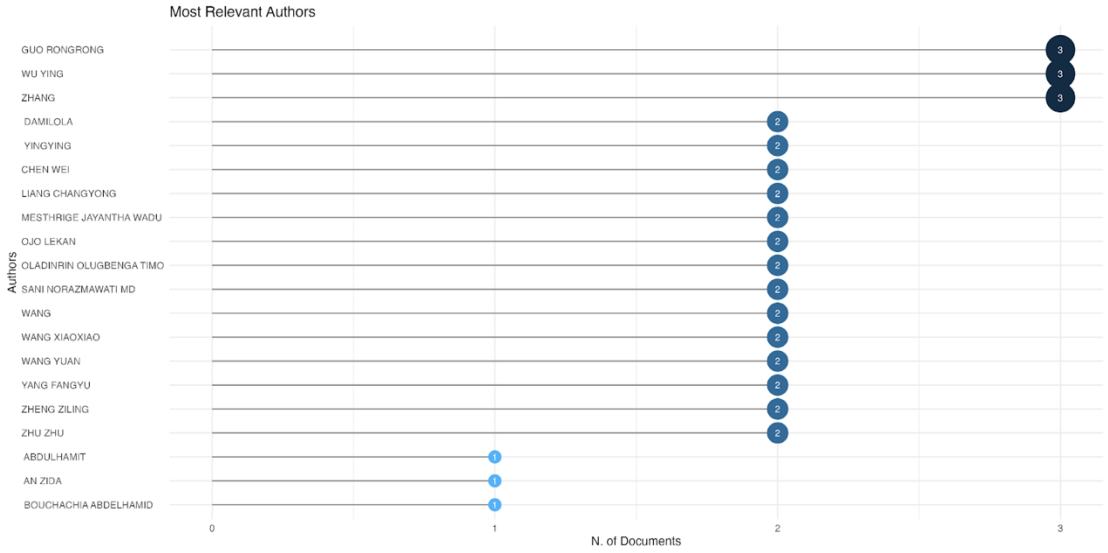


Figure 4. Most Productive Authors

3.5 Journal Analysis

Within the corpus of 113 papers, authors have published their work across 77 different journals. The Figure 5 highlights the top ten journals that have featured research on smart healthcare for the elderly in China. The most popular journal, as indicated by the highest number of publications, is "Frontiers in Public Health." The second one is "Applied Sciences-Basel," which also appears to be a significant publisher in this area of study. The prominence of these journals reflects their relevance and influence in disseminating knowledge about smart healthcare innovations for the elderly. Other notable journals include "Electronics," "IEEE Internet of Things Journal," and "Sustainability," each contributing significantly to the discourse.

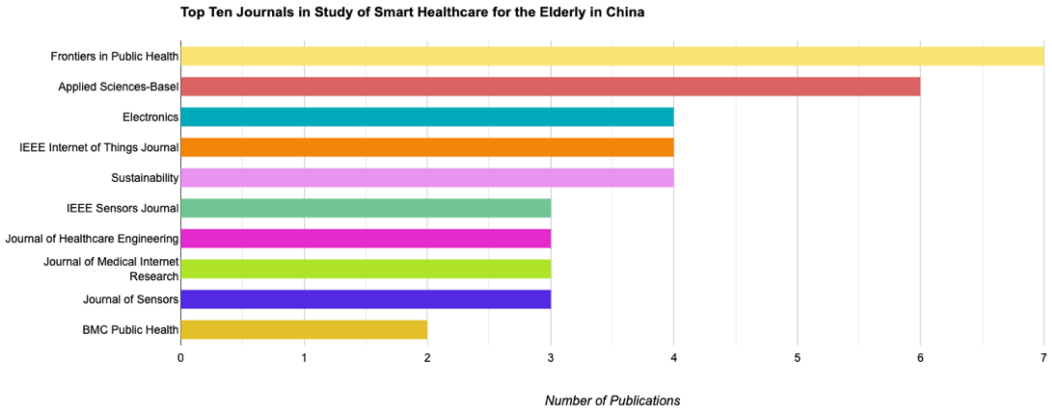


Figure 5 Top 10 Journals in Study of Smart Healthcare for the Elderly in China

3.6 Keywords Analysis

The keyword analysis reveals a multifaceted focus on smart healthcare for the elderly in China(Fig.6), with "health" and "system" being the most prominent themes at 11% each. Other significant keywords include "internet" (6%), "internet of things" (6%), and "elderly" (6%), indicating a strong emphasis on technology and its applications for older adults. Additionally, "healthcare" (4%), "smart home" (4%), and "home care" (4%) suggest a focus on healthcare delivery and home-based solutions. Keywords like "activity recognition" (4%), "health monitoring" (4%), and "AI" (3%) highlight the role of advanced technologies in monitoring and managing health, while "challenges" (3%) and "acceptance" (3%) point to research on implementation barriers and user adoption.

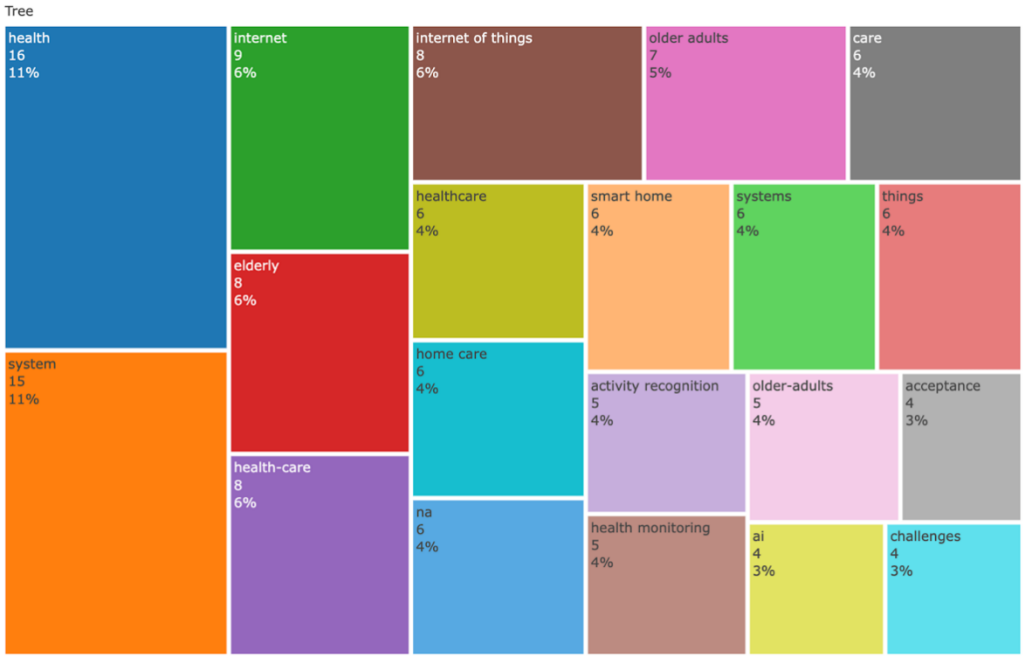


Figure 6. The Top 20 Keywords

4. Discussion

The rapid advancement of technology has led to the development of smart devices, systems, and services that are transforming various aspects of daily life, particularly for older adults (Sun et al., 2024). However, the adoption and effective utilization of these technologies face several challenges, including user knowledge, privacy concerns, and the need for user-centric design. The use of wearable devices, smart home systems, and remote health monitoring technologies is becoming more prevalent, offering real-time health data and personalized care. For instance, AI-driven systems can analyze data from IoT devices to provide predictive analytics and early disease detection (Patel & Pal, 2024). Additionally, smart home systems are being developed to support independent living by integrating various sensors and devices to monitor the home environment and detect emergencies (Yang et al., 2021).

Smart health monitoring systems are becoming more sophisticated, with capabilities to monitor vital signs, physical activity, sleep patterns, and even detect anomalies in real-time. These systems can help in early detection of health issues, reducing hospital visits, and improving overall health management for the elderly (Choi et al., 2021). In addition to health monitoring, smart technologies are also being used to enhance social engagement and psychological well-being among older adults.

Addressing the challenges associated with smart technologies for the elderly requires collaborative efforts from researchers, developers, healthcare providers, and policymakers (Hong et al., 2022). Providing education and training to older adults to enhance their digital literacy and confidence in using smart technologies is essential (Liu et al., 2023). Developing regulations and policies to ensure the safety, efficacy, and ethical use of smart technologies in elderly care is also crucial. Encouraging interdisciplinary research that combines insights from gerontology, engineering, computer science, and healthcare can lead to comprehensive solutions. Finally, fostering continuous innovation in smart technologies to address emerging needs and challenges in elderly care, such as the development of new sensors, AI algorithms, and user interfaces, is necessary to ensure that these technologies remain effective and relevant (Mao et al., 2024).

The trends indicate a promising future for the application of smart technologies in elderly care, with the potential to significantly improve the quality of life, health outcomes, and social engagement for older adults. However, achieving these benefits requires addressing the identified challenges through user-centric design, privacy protections, and collaborative efforts across multiple stakeholders. By focusing on continuous innovation and interdisciplinary research, smart technologies can play a crucial role in supporting the well-being of the elderly population in an increasingly aging society.

In the realm of smart healthcare for the elderly, several key strategies are essential for maximizing the benefits of technological advancements. Enhancing Digital Literacy is a fundamental step, as it involves providing comprehensive training and support to help older adults become more adept at using smart devices and systems (Zhu et al. ,2023). This not only boosts their confidence but also ensures they can effectively utilize these technologies for their health and well-being. Addressing Privacy and Security Concerns is equally crucial, especially as smart technologies become more intertwined with healthcare. Robust data protection measures and clear regulations are necessary to safeguard personal health data, ensuring that older adults can trust the systems they use. Developing User-

Friendly Designs is another critical aspect, focusing on simplicity, accessibility, and ease of use. By prioritizing these elements, smart technologies can bridge the digital divide and make it easier for older adults to fully benefit from these innovations (Deng et al., 2024). Lastly, Promoting Global Collaboration among researchers, developers, and policymakers from different countries can significantly accelerate the development and implementation of smart healthcare systems. By sharing best practices and learning from international models, more effective and inclusive solutions can be developed, ultimately enhancing the quality of life for older adults through the effective use of smart technologies.

5. Limitations of the Study

The study's reliance on a single database, such as the Web of Science Core Collection, may exclude important research published in other databases or grey literature. Bibliometric analysis focuses on quantitative aspects of publications, such as publication counts and keyword frequencies, but may overlook the qualitative depth and impact of individual studies. Meanwhile the analysis may not fully capture the nuances and complexities of interdisciplinary research, which is common in the field of smart healthcare systems.

The study focuses only on the period from 2020 to 2025. This short time frame may not provide a comprehensive understanding of the long-term trends and historical context of research in this field. A longer time frame could offer deeper insights into the evolution of smart healthcare systems. By focusing solely on China, the analysis may overlook unique challenges and innovative solutions from other regions that could be relevant to China's context. A broader global comparison could help identify best practices and areas for international collaboration.

6. Conclusion

Research utilizing bibliometric analysis reveals that the advancement of smart healthcare systems, particularly smart home technologies, can significantly transform the lives of older adults. In conclusion, while smart technologies offer significant potential for improving the quality of life and health outcomes for older adults, addressing the identified challenges and focusing on user-centric design are essential for their successful integration. Future research and development should prioritize enhancing digital literacy, ensuring data privacy, and creating user-friendly designs to maximize the benefits of smart healthcare systems for the elderly in China.

Bibliometric analysis has emerged as a powerful tool to systematically review and identify trends in the field of smart healthcare for the elderly. Studies have shown that the focus of research has shifted from traditional telemedicine to a more comprehensive digital health approach, emphasizing individual health outcomes and overall well-being. This shift reflects an evolving healthcare paradigm where technology extends beyond remote clinical interactions to a system that enhances personalized health management. Additionally, the analysis reveals that countries like the United States, China, and Canada are leading contributors in this field, with strong thematic overlaps in areas such as dementia care, machine learning, and wearable health monitoring technologies.

Appendix A

No.	Authors	TI	PY	DI
1	ZHOU J, 2025, INT J HUM-COMPUT INTERACT	Grand Challenges of Smart Technology for Older Adults	2025	10.1080/10447318.2025.2457003
2	ZHANG H, 2025, FRONT PUBLIC HEALTH	The impact of information technology applications on the quality of life of disabled older adults in nursing homes in China: a qualitative study	2025	10.3389/fpubh.2025.1560306
3	ZHANG B, 2023, FRONT PUBLIC HEALTH	Promoting active aging through assistive product design innovation: a preference-based integrated design framework	2023	10.3389/fpubh.2023.1203830
4	GUO R, 2025, J MED INTERNET RES	Efficacy of an Intelligent and Integrated Older Adult Care Model on Quality of Life Among Home-Dwelling Older Adults: Randomized Controlled Trial	2025	10.2196/67950
5	GUO Q, 2024, FRONT PUBLIC HEALTH	Construction and optimization of health behavior prediction model for the older adult in smart older adult care	2024	10.3389/fpubh.2024.1486930
6	CHEN Y, 2025, CLIN INTERV AGING	Digital Inclusion Pathways and Influencing Factors	2025	10.2147/CIA.S518045

		Among Older Adults in Outpatient Settings: A Grounded Theory Study		
7	LUO J, 2025, BEHAV SCI	From Acceptance to Dependence: Exploring Influences of Smart Healthcare on Continuous Use Intention of Mobile Health Services Among Older Adults with Chronic Illnesses in China	2025	10.3390/bs15010019
8	YANG D, 2024, FRONT PUBLIC HEALTH	Wireless sensor network-based health monitoring and smart home assistance for the older adults in sports and wellness towns	2024	10.3389/fpubh.2024.1399648
9	WANG Y, 2024, FRONT PUBLIC HEALTH	Analysis of demand and influencing factors for smart senior care among older adults in underdeveloped regions of western China: a case study of Lanzhou	2024	10.3389/fpubh.2024.1337584
10	SHEN Z, 2024, SMART CITIES	Fit Islands: Designing a Multifunctional Virtual Urban Community to Promote Healthy Aging for Chinese Older Adults	2024	10.3390/smartcities7010009
11	WANG C, 2024, IEEE SENS J	Detection of Eating Gestures in Older Persons Using IMU Sensors With Multistage Temporal Convolutional Network	2024	10.1109/JSEN.2024.3460651
12	ZHU R, 2021, SUSTAINABILITY	Prediction of the Hypertension Risk of the Elderly in Built Environments Based on the LSTM Deep Learning and Bayesian Fitting Method	2021	10.3390/su13105724
13	ZHU Y, 2023, INT J COMPUT INTELL SYST	Global Trends in the Study of Smart Healthcare Systems for the Elderly: Artificial Intelligence Solutions	2023	10.1007/s44196-023-00283-w
14	AHMAD I, 2022, IEEE ACCESS	Emerging Technologies for Next Generation Remote Health Care and Assisted Living	2022	10.1109/ACCESS.2022.3177278
15	JU C, 2024, FRONT PUBLIC HEALTH	Changes in patterns of multimorbidity and associated with medical costs among Chinese middle-aged and older adults from 2013 to 2023: an analysis of repeated cross-sectional surveys in Xiangyang, China	2024	10.3389/fpubh.2024.1403196
16	HUANG Q, 2024, BMC PUBLIC HEALTH	Sleeping more than 8 h: a silent factor contributing to decreased muscle mass in Chinese community-dwelling older adults	2024	10.1186/s12889-024-18520-y
17	GUO R, 2025, BMC GERIATR	Development and usability testing of an integrated geriatric care model (SMART	2025	10.1186/s12877-025-05829-5

		system) to promote integrated home-based geriatric care		
18	QIN C, 2023, INTELL SERV ROBOT	A multimodal domestic service robot interaction system for people with declined abilities to express themselves	2023	10.1007/s11370-023-00466-6
19	ZHAO J, 2022, FRONT PUBLIC HEALTH	Impact of smart health systems on the behavior of older adults under community healthcare	2022	10.3389/fpubh.2022.1056817
20	HUANG S, 2024, ISCIENCE	A contactless monitoring system for accurately predicting energy expenditure during treadmill walking based on an ensemble neural network	2024	10.1016/j.isci.2024.109093
21	WANG X, 2023, IEEE SENS LETT	Edge-Assisted IoMT-Based Smart-Home Monitoring System for the Elderly With Chronic Diseases	2023	10.1109/LSENS.2023.3240670
22	MESTHRIGE JW, 2023, J AGING ENVIRON	Critical Barriers of Using Smart Home Technologies (SHTs) to the Elderly in Hong Kong	2023	10.1080/26892618.2022.2062805
23	YU J, 2023, HEALTHCARE	Long-Term Adoption or Abandonment of Smart Technology in the Chinese Elderly Home Care Environment: A Qualitative Research Study	2023	10.3390/healthcare11172440
24	TANG V, 2022, J ORGAN END USER COMPUT	A Two-Echelon Responsive Health Analytic Model for Triggering Care Plan Revision in Geriatric Care Management	2022	10.4018/JOEUC.289224
25	GUO R, 2025, J MED INTERNET RES-a	Translation, Cross-Cultural Adaptation, and Psychometric Validation of the Health Information Technology Usability Evaluation Scale in China: Instrument Validation Study	2025	10.2196/67948
26	LIU Y, 2020, APPL SCI-BASEL	Constructing a Smart Home for Future Elders toward All-around Happiness: Taking Connectivity as the Core Element	2020	10.3390/app10165690
27	CAO C, 2023, DIGIT HEALTH	How to promote the healthy development of continuous participation in smart medical and elderly care systems: The dual perspective of perceived value and risk	2023	10.1177/20552076231197425
28	LIU T, 2025, HEALTH INF MANAG J	Developing a minimum dataset for smart aged care service platforms in China	2025	10.1177/18333583251327663
29	SUN X, 2020, BMC PUBLIC HEALTH	Internet use and need for digital health technology among the elderly: a cross-sectional survey in China	2020	10.1186/s12889-020-09448-0

30	CHEN D, 2024, IEEE INTERNET THINGS J	Flexible and Fine-Grained Access Control for EHR in Blockchain-Assisted E-Healthcare Systems	2024	10.1109/JIOT.2023.3328382
31	YU Y, 2025, APPL SCI-BASEL	Deep Learning-Driven Geospatial Modeling of Elderly Care Accessibility: Disparities Across the Urban-Rural Continuum in Central China	2025	10.3390/app15094601
32	LI A, 2024, BMC MED INFORM DECIS MAK	KGSCS-a smart care system for elderly with geriatric chronic diseases: a knowledge graph approach	2024	10.1186/s12911-024-02472-9
33	WANG B, 2021, J SENS	Optimization of a Wireless Sensor Network-Based Smart Elderly Location Management System	2021	10.1155/2021/2760746
34	WANG R, 2023, GLOB TRANSIT	Initiation of the smart home wards as a new model for home-based rehabilitation for the elderly	2023	10.1016/j.glt.2023.02.001
35	ZHANG F, 2023, SAF SCI	Developing smart buildings to reduce indoor risks for safety and health of the elderly: A systematic and bibliometric analysis	2023	10.1016/j.ssci.2023.106310
36	WANG Y, 2024, BUILDINGS-BASEL	Investigating the Behavioral Intention of Smart Home Systems among Older People in Linyi City	2024	10.3390/buildings14103145
37	OLADINRIN OT, 2023, SUSTAINABILITY	Smart Home Technologies to Facilitate Ageing-in-Place: Professionals Perception	2023	10.3390/su15086542
38	ZHU Z, 2022, MATH PROBL ENG	Modeling of Smart Watch and System Construction Method for the Elderly Based on Big Data	2022	10.1155/2022/2606781
39	YANG L, 2023, WIREL NETW	Data monitoring for a physical health system of elderly people using smart sensing technology	2023	10.1007/s11276-023-03429-y
40	ZHU Z, 2022, J SENS	Design of Health Detection System for Elderly Smart Watch Based on Biosignal Acquisition	2022	10.1155/2022/6988001
41	YANG M, 2023, ACS APPL MATER INTERFACES	Transparent, Stretchable, and Adhesive Conductive Ionic Hydrogel- Based Self-Powered Sensors for Smart Elderly Care Systems	2023	10.1021/acsami.2c22331
42	MA Y, 2023, BUILDINGS-BASEL	How Does the Intelligent Monitoring System Influence the Sense of Security of the Elderly in Home Care? A Case Study of the Hubin Community in Ningde City	2023	10.3390/buildings13051255
43	YANG C, 2022, SUSTAINABILITY	A Sustainable, Interactive Elderly Healthcare System	2022	10.3390/su14074204

		for Nursing Homes: An Interdisciplinary Design		
44	WANG Y, 2024, PLOS ONE	Factors affecting the elderly's behavioral intention toward smart home systems: A cross-sectional study from China's eastern coast	2024	10.1371/journal.pone.0311280
45	WANG H, 2024, CHINA CDC WEEKLY	Analysis of Hot Topics Regarding Global Smart Elderly Care Research-1997-2021	2024	10.46234/ccdcw2024.032
46	TANG H, 2022, WIREL COMMUN MOB COMPUT	RETRACTED: Health Care Intervention Measures for the Elderly under the Smart Sports Rehabilitation Mode under the Background of Big Data (Retracted Article)	2022	10.1155/2022/1652819
47	LI S, 2020, COMPUT MATH METHOD MED	A Simple Framework of Smart Geriatric Nursing considering Health Big Data and User Profile	2020	10.1155/2020/5013249
48	QIN Y, 2022, COMPUT ELECTR ENG	A management method of chronic diseases in the elderly based on IoT security environment	2022	10.1016/j.compeleceng.2022.108188
49	PU Y, 2025, J COMPUT METHODS SCI ENG	Design of smart elderly care emotion recognition and elderly care system based on transfer learning	2025	10.1177/14727978251337893
50	SHUWEI L, 2025, THERM SCI ENG PROG	Indoor energy conservation and intelligent elderly care rehabilitation based on ambient light sensing in the Internet of Things	2025	10.1016/j.tsep.2025.103289
51	CHEN H, 2022, FIBRES TEXT EAST EUR	Research and Design of Smart Care-Giving Clothing for Disabled Elderly	2022	10.2478/ftee-2022-0034
52	DING J, 2020, IEEE TRANS CONSUM ELECTRON	A WiFi-Based Smart Home Fall Detection System Using Recurrent Neural Network	2020	10.1109/TCE.2020.3021398
53	LIU C, 2023, PROCESSES	Adaptive Optimization Design of Building Energy System for Smart Elderly Care Community Based on Deep Deterministic Policy Gradient	2023	10.3390/pr11072155
54	HUANG Z, 2024, INTERNET THINGS	Full-coverage unobtrusive health monitoring of elders at homes	2024	10.1016/j.iot.2024.101182
55	WANG X, 2022, J SENS	RETRACTED: Application of ``TCM plus Smart Elderly Care'' in the Medical-Nursing Care Integration Service System (Retracted Article)	2022	10.1155/2022/5154528
56	SHI T, 2022, INT J ENVIRON RES PUBLIC HEALTH	A Regulatory Game Analysis of Smart Aging Platforms Considering Privacy Protection	2022	10.3390/ijerph19095778
57	JIA M, 2019, IEEE ACCESS	Modeling and Analysis of First Aid Command and	2019	10.1109/ACCESS.2019.2954451

		Dispatching System of Cloud Medical System		
58	SHANG C, 2020, IEEE INTERNET THINGS J	FIID: Feature-Based Implicit Irregularity Detection Using Unsupervised Learning From IoT Data for Homecare of Elderly	2020	10.1109/JIOT.2020.2990556
59	WU J, 2025, SENSORS	An Algorithm for Mining the Living Habits of Elderly People Living Alone Based on AIoT	2025	10.3390/s25072299
60	ZHAO Y, 2021, PLOS ONE	The expectations and acceptability of a smart nursing home model among Chinese elderly people: A mixed methods study protocol	2021	10.1371/journal.pone.0255865
61	ELAHI H, 2021, NEUROCOMPUTING	A human-centered artificial intelligence approach for privacy protection of elderly App users in smart cities	2021	10.1016/j.neucom.2020.06.149
62	ZHOU F, 2024, ELECTRONICS	Acdim: A Cardiovascular Disease Risk Prediction Model Based on TabNet and AdaBoost for Smart Aging	2024	10.3390/electronics13244892
63	WANG C, 2024, LAND	Evaluating Smart Community Development in China from the Perspective of Residents' Sense of Safety: An Analysis Using Criteria Importance through Intercriteria Correlation and Fuzzy Comprehensive Evaluation Approaches	2024	10.3390/land13091434
64	HUANG W, 2024, SAGE OPEN	Research on Aging-adaptive Auxiliary Construction of Smart Communities	2024	10.1177/21582440241254689
65	CHEN S, 2025, CURR PSYCHOL	The evaluation of rural elderly care service quality under group public health management with SERVQUAL model	2025	10.1007/s12144-025-08086-2
66	LI R, 2021, MICROMACHINES	Smart Wearable Sensors Based on Triboelectric Nanogenerator for Personal Healthcare Monitoring	2021	10.3390/mi12040352
67	LIU X, 2025, DIGIT HEALTH	Synergistic evaluation system of ``technology and service'' in smart elderly care institutions in China	2025	10.1177/20552076251326681
68	HSU WL, 2023, SENS MATER	Importance of Sensor Technology in Evaluation of Smart Monitoring System of Nursing Home	2023	10.18494/SAM4457
69	DONG F, 2023, SUSTAINABILITY	EWM-FCE-ODM-Based Evaluation of Smart Community Construction: From the Perspective of Residents' Sense of Gain	2023	10.3390/su15086587

70	CHEN X, 2024, APPL SCI-BASEL	Research on the Spatial and Temporal Distribution Evolution and Sustainable Development Mechanism of Smart Health and Elderly Care Demonstration Bases Based on GIS	2024	10.3390/app14020780
71	XU L, 2021, J GREY SYST	Evaluation and Analysis of Smart Community Elderly Care Service Quality Based on The Two-stage Decision Model with Grey Synthetic Measures under Hesitant Fuzzy Situation	2021	NA
72	WANG Y, 2025, ACS APPL ELECTRON MATER	Smart Self-Powered System Based on Supramolecular Conductive Hydrogel for Assistive Elderly Living	2025	10.1021/acsaelm.5c00497
73	ZHANG Y, 2025, TECHNOL FORECAST SOC CHANG	Gamification for elderly well-being: Effects on experience and engagement	2025	10.1016/j.techfore.2025.124155
74	CHEN X, 2024, IEEE TRANS CONSUM ELECTRON	IG-GCN: Empowering e-Health Services for Alzheimers Disease Prediction	2024	10.1109/TCE.2024.3439594
75	WU Y, 2024, WIREL PERS COMMUN	Cyber-Physical Wireless Networks for Smart Health Monitoring for Elderly Persons	2024	10.1007/s11277-024-11191-3
76	HAN X, 2022, ANN TRANSL MED	Study on the effect of the ballistocardiography-based ``Internet plus Smart Bed'' health management system on the quality of life of elderly users with chronic diseases	2022	10.21037/atm-22-998
77	LIANG C, 2023, DATA INTELL	Smart Management Information Systems (Smis): Concept, Evolution, Research Hotspots and Applications	2023	10.1162/dint_a_00231
78	JI Q, 2022, COMPUT INTELL NEUROSCI	The Design of the Lightweight Smart Home System and Interaction Experience of Products for Middle-Aged and Elderly Users in Smart Cities	2022	10.1155/2022/1279351
79	MUMTAZ A, 2022, J HEALTHC ENG	Prioritizing and Overcoming Barriers to e-Health Use among Elderly People: Implementation of the Analytical Hierarchical Process (AHP)	2022	10.1155/2022/7852806
80	LI F, 2021, J HEALTHC ENG	RETRACTED: Design of an Interactive Two-Way Telemedicine Service System for Smart Home Care for the Elderly (Retracted Article)	2021	10.1155/2021/6632865
81	ZHANG Z, 2021, IEEE INTERNET THINGS J	LMFNet: Human Activity Recognition Using Attentive 3-D Residual Network	2021	10.1109/JIOT.2020.3033449

		and Multistage Fusion Strategy		
82	GUPTA BB, 2024, CMES-COMP MODEL ENG SCI	LSTM Based Neural Network Model for Anomaly Event Detection in Care-Independent Smart Homes	2024	10.32604/cmes.2024.050825
83	IRFAN M, 2023, IEEE INTERNET THINGS J	An IoT-Based Noncontact ECG System: Sole of the Feet/Hands Palm	2023	10.1109/JIOT.2023.3283037
84	ZHAO R, 2020, MATH BIOSCI ENG	Fuzzy theory analysis on imagery modeling of wearable bracelet in the urbanian health management	2020	10.3934/mbe.2021033
85	WANG Z, 2023, IEEE SENS J	Recognition of Approximate Motions of Human Based on Micro-Doppler Features	2023	10.1109/JSEN.2023.3267820
86	CUI T, 2021, MATERIALS	A Low-Cost, Portable, and Wireless In-Shoe System Based on a Flexible Porous Graphene Pressure Sensor	2021	10.3390/ma14216475
87	CHIN J, 2021, ELECTRONICS	Smart-Object-Based Reasoning System for Indoor Acoustic Profiling of Elderly Inhabitants	2021	10.3390/electronics10121433
88	LI S, 2021, J SENS ACTUAT NETW	Improved Smart Pillow for Remote Health Care System	2021	10.3390/jsan10010009
89	LIU W, 2021, MICROPROCESS MICROSYST	RETRACTED: Medical IoT system platform and elderly patients? femoral shaft fracture nursing (Retracted article. See vol. 106, 2024)	2021	10.1016/j.micpro.2021.103868
90	HOU L, 2024, SCI REP	An autonomous wheelchair with health monitoring system based on Internet of Thing	2024	10.1038/s41598-024-56357-y
91	WANG Y, 2023, ELECTRONICS	A Survey on Ambient Sensor-Based Abnormal Behaviour Detection for Elderly People in Healthcare	2023	10.3390/electronics12071539
92	LI X, 2021, J HEALTHC ENG	Medical Internet of Things to Realize Elderly Stroke Prevention and Nursing Management	2021	10.1155/2021/9989602
93	KONG W, 2021, IEEE ACCESS	Exploratory Data Analysis of Human Activity Recognition Based on Smart Phone	2021	10.1109/ACCESS.2021.3079434
94	ZHANG H, 2022, NANO ENERGY	A high-performance, biocompatible, and degradable piezoresistive-triboelectric hybrid device for cross-scale human activities monitoring and self-powered smart home system	2022	10.1016/j.nanoen.2022.107687
95	LI P, 2021, APPL SCI-BASEL	Gait Phase Estimation Based on User-Walker Interaction Force	2021	10.3390/app11177888
96	KHAN MA, 2025, IET INTELL TRANSP SYST	Smart Steering Wheel: Design of IoMT-Based Non-Invasive Driver Health	2025	10.1049/itr2.70012

		Monitoring System to Enhance Road Safety		
97	YANG Y, 2025, CHEM ENG J	Stretchable and flexible triboelectric sensors with a wide measurement range for human pulse monitoring, motion recognition, and human-computer interaction	2025	10.1016/j.cej.2025.162861
98	IJAZ M, 2021, ELECTRONICS	Integration and Applications of Fog Computing and Cloud Computing Based on the Internet of Things for Provision of Healthcare Services at Home	2021	10.3390/electronics10091077
99	LIN Y, 2024, ACTA POLYM SIN	Flexible Integration and Wearable Application of Belt-type Human Microenvironment Visualization Monitoring System	2024	10.11777/j.issn1000-3304.2024.24028
100	SU M, 2021, APPL SCI-BASEL	Smart Care Using a DNN-Based Approach for Activities of Daily Living (ADL) Recognition	2021	10.3390/app11010010
101	LI J, 2024, IEEE SENS J	The CNT/Jute Rope Composite Fabric Strain Sensor Based on the Twining-Cladding Weaved Structure for High-Performance Smart Carpet Applications	2024	10.1109/JSEN.2024.3421665
102	HUANG M, 2022, CONTRAST MEDIA MOL IMAGING	RETRACTED: Surgical Strategy and Prognosis of Pancreatic Neuroendocrine Tumors Based on Smart Medical Imaging (Retracted Article)	2022	10.1155/2022/8752375
103	FANG Y, 2023, APPL SCI-BASEL	Wi-Senser: Contactless Head Movement Detection during Sleep Utilizing WiFi Signals	2023	10.3390/app13137572
104	LI X, 2022, ACS APPL NANO MATER	Smart Diaper Based on Integrated Multiplex Carbon Nanotube-Coated Electrode Array Sensors for In Situ Urine Monitoring	2022	10.1021/acsanm.1c04220
105	GUO P, 2024, COMPUT SECUR	A privacy preserving four-factor authentication protocol for internet of medical things	2024	10.1016/j.cose.2023.103632
106	ZHANG Y, 2022, CHIN SCI BULL-CHIN	Sensing, computing and intervention for sleep health	2022	10.1360/TB-2021-0911
107	LIU Z, 2024, SOFT COMPUT	Distribution characteristics of inhalable particulate pollutants and their effects on cardiopulmonary respiratory system of outdoor football players in a smart healthcare system	2024	10.1007/s00500-023-09589-5
108	HUANG X, 2022, RENEW SUST ENERG REV	Realistic representation of city street-level human	2022	10.1016/j.rser.2022.112919

		thermal stress via a new urban climate-human coupling system		
109	SODHRO AH, 2021, SENSORS	AI-Enabled Framework for Fog Computing Driven E-Healthcare Applications	2021	10.3390/s21238039
110	ZHANG C, 2023, MICROSYST NANOENG	A nanonewton-scale biomimetic mechanosensor	2023	10.1038/s41378-023-00560-w
111	XIAO J, 2025, J MED INTERNET RES	Smart Pharmaceutical Monitoring System With Personalized Medication Schedules and Self-Management Programs for Patients With Diabetes: Development and Evaluation Study	2025	10.2196/56737
112	SHENG B, 2022, MEASUREMENT	Smart fall prediction paradigm for community-dwelling seniors through fitness screening protocols and machine learning	2022	10.1016/j.measurement.2022.111584
113	GAO W, 2020, J PEDIATR NURS	Development and Pilot Testing a Self-Reported Pediatric PROMIS App for Young Children Aged 5-7 Years	2020	10.1016/j.pedn.2020.04.003

References

1. Choi, Y. K., Thompson, H. J., & Demiris, G. (2021). Internet-of-Things smart home technology to support aging-in-place: Older adults' perceptions and attitudes. *Journal of Gerontological Nursing*, *47*(4), 15–21. https://doi.org/10.3928/00989134-20210310-03

2. Deng, J., Yao, D., Deng, Y., Liu, Z., Yang, J., & Gong, D. (2024). Study on the impact of smart city construction on the health of the elderly population——A quasi-natural experiment in China. *PLOS ONE*, *19*(6), e0305897. https://doi.org/10.1371/journal.pone.0305897

3. Dermody, G., Fritz, R., Glass, C., Dunham, M., & Whitehead, L. (2023). Family caregiver readiness to adopt smart home technology to monitor care—Dependent older adults: A qualitative exploratory study. *Journal of Advanced Nursing*, *80*(2), 628–643. https://doi.org/10.1111/jan.15826

4. Ho, C. M. B., Hana, J., & Park, S. J. (2022). IoT based health monitoring system - Recent trends and directions. *Gerontechnology*, *21*(s), 1–1. https://doi.org/10.4017/gt.2022.21.s.524.pp1

5. Hong, Y.-K., Wang, Z.-Y., & Cho, J. Y. (2022). Global research trends on smart homes for older adults: Bibliometric and scientometric analyses. *International Journal of Environmental Research and Public Health*, *19*(22), 14821. https://doi.org/10.3390/ijerph192214821

6. Hu, K.-J., Chang, C.-W., & Chang, Y.-S. (2023). Application for detecting falls for elderly persons through internet of things combined with pulse sensor. *Sensors and Materials*, *35*(11), 3655. https://doi.org/10.18494/sam4641

7. Hu, Y. (2023). Analysis and forecast of contemporary Chinese population. *Advances in Economics, Management and Political Sciences*, *55*(1), 226–237. https://doi.org/10.54254/2754-1169/55/20231012

8. Hung, J. (2022). Smart elderly care services in China: Challenges, progress, and policy development. *Sustainability*, *15*(1), 178. https://doi.org/10.3390/su15010178

9. Li, R. (2023). The impact of population aging on GDP and medical expenditure in china. *Advances in Economics, Management and Political Sciences*, *45*(1), 214–221. https://doi.org/10.54254/2754-1169/45/20230288

10. Liu, X., Chau, K.-Y., Liu, X., & Wan, Y. (2023). The progress of smart elderly care research: A scientometric analysis based on CNKI and WOS. *International Journal of Environmental Research and Public Health*, *20*(2), 1086. https://doi.org/10.3390/ijerph20021086

11. Luo, Y., Su, B., & Zheng, X. (2021). Trends and challenges for population and health during population aging — China, 2015–2050. *China CDC Weekly*, *3*(28), 593–598. https://doi.org/10.46234/ccdcw2021.158

12. Ma, D., Zhou, K., Xu, J., & Qian, Y. (2023). Industrial structure upgrading, population aging and migration: An empirical study based on Chinese provincial panel data. *PLOS ONE*, *18*(10), e0291718. https://doi.org/10.1371/journal.pone.0291718

13. Mao, Q., Mao, Y., Sun, Q., & Xu, L. (2024). Smart transition pathways and development incentive mechanism of China's smart community elderly care industry under market dominance: Considering a multi-subjective behavior game. *PLOS ONE*, *19*(5),

e0297696. https://doi.org/10.1371/journal.pone.0297696

14. Nanda, M., & Sharma, R. (2021). A review of patient satisfaction and experience with telemedicine: A virtual solution during and beyond COVID-19 Pandemic. *Telemedicine and E-Health*, *27*(12), 1325–1331. https://doi.org/10.1089/tmj.2020.0570

15. Omboni, S., Padwal, R. S., Alessa, T., Benczúr, B., Green, B. B., Hubbard, I., Kario, K., Khan, N. A., Konradi, A., Logan, A. G., Lu, Y., Mars, M., McManus, R. J., Melville, S., Neumann, C. L., Parati, G., Renna, N. F., Ryvlin, P., Saner, H., … Wang, J. (2022). The worldwide impact of telemedicine during COVID-19: Current evidence and recommendations for the future. *Connected Health*. https://doi.org/10.20517/ch.2021.03

16. Patel, B., & Kumar Pal, Prof. S. (2024). Revolutionizing disease diagnosis: Integrating artificial intelligence and IOT in smart healthcare systems. *SMART MOVES JOURNAL IJOSCIENCE*, 15–26. https://doi.org/10.24113/ijoscience.v10i3.514

17. Sun, S., Jiang, L., & Zhou, Y. (2024). Associations between perceived usefulness and willingness to use smart healthcare devices among Chinese older adults: The multiple mediating effect of technology interactivity and technology anxiety. *DIGITAL HEALTH*, *10*. https://doi.org/10.1177/20552076241254194

18. Wang, M.-Y., Sung, H.-C., & Liu, J.-Y. (2022). Population aging and its impact on human wellbeing in China. *Frontiers in Public Health*, *10*. https://doi.org/10.3389/fpubh.2022.883566

19. Yang, P., Bi, G., Qi, J., Wang, X., Yang, Y., & Xu, L. (2021). Multimodal wearable intelligence for dementia care in healthcare 4.0: A survey. *Information Systems Frontiers*, *27*(1), 197–214. https://doi.org/10.1007/s10796-021-10163-3

20. Zhu, Y., Yang, Q., & Mao, X. (2023a). Global trends in the study of smart healthcare systems for the elderly: Artificial intelligence solutions. *International Journal of Computational Intelligence Systems*, *16*(1). https://doi.org/10.1007/s44196-023-00283-w

TECHNICAL SCIENCES

РОЛЬ ТЕХНОЛОГИИ БЛОКЧЕЙН В КИБЕРБЕЗОПАСНОСТИ: ПРИМЕНЕНИЕ, ВЫЗОВЫ И ПЕРСПЕКТИВЫ

Ахмедова А.
Нахчыванский Государственный Университет
ORCID ID: https://orcid.org/0009-0004-9657-5649
Асадова Ш.
Нахчыванский Государственный Университет

THE ROLE OF BLOCKCHAIN TECHNOLOGY IN CYBERSECURITY: APPLICATIONS, CHALLENGES AND PERSPECTIVES

Ahmadova A.
Nakhchivan State University
ORCID ID: https://orcid.org/0009-0004-9657-5649
Asadova S.
Nakhchivan State University
DOI: 10.5281/zenodo.19828112

АННОТАЦИЯ

В данной работе рассматривается трансформирующая роль технологии блокчейн в укреплении современных основ кибербезопасности перед лицом усложняющихся угроз. Исследование подчеркивает, как децентрализованная и криптографическая природа блокчейна снижает системные уязвимости, в частности, устраняя риски, связанные с едиными точками отказа и DDoS-атаками. Кроме того, интеграция блокчейна с искусственным интеллектом и облачными вычислениями анализируется как проактивная стратегия для обнаружения угроз в реальном времени. Особое внимание уделяется обеспечению безопасности экосистемы Интернета вещей (IoT) с помощью протоколов децентрализованной идентификации и аутентификации. В заключение рассматриваются критические вызовы внедрения, такие как энергоэффективность и нормативно-правовая база, что определяет блокчейн как фундаментальный стандарт цифровой целостности в будущем.

ABSTRACT

This paper examines the transformative role of blockchain technology in enhancing modern cybersecurity frameworks against increasingly sophisticated threats. The study highlights how the decentralized and cryptographic nature of blockchain mitigates systemic vulnerabilities, specifically addressing the risks associated with Single Points of Failure and DDoS attacks. Furthermore, the integration of blockchain with artificial intelligence and cloud computing is explored as a proactive strategy for real-time threat detection and autonomous response. Special emphasis is placed on securing the Internet of Things (IoT) ecosystem through decentralized identification and authentication protocols. Finally, the research addresses critical implementation challenges such as energy efficiency and regulatory frameworks, positioning blockchain as a fundamental standard for future digital integrity.

Ключевые слова: технология блокчейн, кибербезопасность, целостность данных, децентрализованные системы.

Keywords: blockchain technology, cybersecurity, data integrity, decentralized systems.

Introduction

In the technological paradigm of the modern era, the acceleration of digitalization processes has fundamentally transformed the entire spectrum of human activity. While digital communication channels in previous decades were characterized solely by simple text exchange and limited data transmission, the current landscape features generative artificial intelligence platforms, complex banking-financial ecosystems, and integrated e-government infrastructures. While ensuring high efficiency in data management, this evolution has also increased the complexity of critical information systems, rendering them vulnerable to larger-scale external interventions.

In this context, the insufficiency of traditional cybersecurity architectures against contemporary threats necessitates the development of more innovative and resilient defense mechanisms. The integration of blockchain technology into the cybersecurity ecosystem offers strategic security solutions by enabling a transition to decentralized structures. The technology in question serves as an effective methodological framework for preserving data integrity, increasing the transparency of authorization processes, and eliminating potential security vulnerabilities.

The evolution of cyber-threats and traditional defense mechanisms

The extensive expansion of the digital ecosystem has, in turn, created a fertile environment for the proliferation of complex and high-risk cyber-threats. Conventional protection methods demonstrate insufficient effectiveness in countering modern organized cyber-attacks, particularly in cases involving unauthorized data acquisition, manipulation of confidential information, and the total paralysis of critical infrastructure systems.

These deficiencies are directly related to the fact that centralized management models possess a Single Point of Failure and remain structurally weak against external interventions.

Strategic solution: Blockchain technology and the security paradigm

The gaps emerging in the current cybersecurity landscape render the implementation of fundamentally more reliable, transparent, and cryptographically grounded technologies inevitable for the protection of digital assets. In this context, blockchain solutions offer an innovative defense paradigm by ensuring data integrity and availability through Distributed Ledger Technology (DLT). In such an environment, blockchain emerges not merely as a means of data storage, but as a strategic tool for enhancing cyber resilience and establishing a decentralized trust model.

Blockchain applications in cybersecurity

Initially implemented exclusively within the cryptocurrency sphere, blockchain has now evolved into one of the fundamental pillars of cybersecurity. This technology ensures data integrity and immutability [8]. Due to its decentralized architecture, data is not stored on a single server but is distributed among network participants.

The Bitcoin ecosystem serves as a primary example. While an attack on a central server in traditional banking systems jeopardizes the entire system, in blockchain-based systems, data is synchronized across thousands of nodes. Consequently, unauthorized interventions by hackers at several points do not compromise the overall security of the network. Furthermore, this technology accelerates processes while reducing the costs associated with digital identification.

DDoS threats in digital infrastructure and their consequences

The rapid expansion of the global digital infrastructure has significantly increased both the frequency and the destructive scale of Distributed Denial of Service (DDoS) attacks. These types of cyber interventions paralyze the availability of critical services by overwhelming centralized server architectures with excessive malicious request traffic [5]. Consequently, for organizations, these attacks are not limited to direct financial losses but also create serious strategic risks, leading to the undermining of corporate reputation and the long-term degradation of user trust.

Blockchain architecture: Cryptographic resilience and Anti-DDoS mechanisms

In countering such sophisticated threats, blockchain technology establishes a fundamental protective barrier through the principle of storing data in a cryptographic chain structure. In this system, each block references the hash value of the preceding block, forming a digital sequence characterized by a chain-like succession that is virtually impossible to manipulate [3]. The decentralized nature of blockchain, particularly in distributed Domain Name System (DNS) solutions, ensures the absence of a single target point (Single Point of Failure), thereby maximizing the network's immunity to DDoS attacks and its overall **cyber resilience**.

Technological synergy: Integration of artificial intelligence, cloud computing, and blockchain

In the near future, the convergence of blockchain technology with Artificial Intelligence (AI) and cloud computing systems will initiate a qualitatively new phase in cyber-threat monitoring and preventive defense strategies. This triple integration will facilitate the intelligent analysis of anomalies in real-time and the immutable recording of such data on the blockchain, thereby creating conditions for the formation of autonomous and high-speed response mechanisms against cyber incidents. Such an ecosystem will fundamentally strengthen corporate and state-level security architectures by making data management in the digital environment more transparent and resilient to manipulation.

IoT security and institutional regulatory perspectives

The implementation of decentralized security protocols for the identification and authentication of devices, particularly within the Internet of Things (IoT) ecosystem, is considered one of the priority directions of modern cybersecurity science [1, 2]. Blockchain-based distributed identification models will not only ensure secure interactions among billions of heterogeneous devices within the network but also minimize the risks inherent in centralized management systems. With the enhancement of energy efficiency, optimization of technical complexity, and the establishment of international legal regulatory frameworks, blockchain is poised to become a fundamental standard providing absolute transparency and integrity in the global digital environment.

Conclusion

Blockchain technology, through its decentralized architecture and principles of cryptographic security, is paving the way for revolutionary transformations in the field of cybersecurity [7]. Despite current technical challenges, the implementation of this technology is indispensable for the establishment of a more resilient, efficient, and attack-resistant digital ecosystem [6].

References

1. Seyyar, Y. E. (2021). Cybersecurity in IoT systems for the transportation sector: Threats, attacks, and protection strategies. *Journal of Engineering and Technology*.

2. Ahakonye, L. A. C., Nwakanma, C. I., & Kim, D. S. (2022). Tides of Blockchain in IoT Cybersecurity. *IEEE Access*.

3. Goel, A., & Rahulamathavan, Y. (2020). A Comparative Survey of Centralised and Decentralised Identity Management Systems: Analysing Scalability, Security, and Feasibility. *Future Internet*.

4. Yacan, İ. (2021). Endüstri 4.0 Teknolojileri ve Toplum 5.0 Kavramı. *Yeni Fikir Dergisi*, 13(27), 31–39.

5. Aydın, Ö., & Yükçü, S. (2019). Assessment of Blockchain Technology in terms of Benefit-Cost in Cyber Attack Prevention. *Journal of Business Research*.

6. Ahmadova, A. (2022). The Potential Of Blockchain Technology In Education: Reliability, Efficiency And Future Strategies. *International Journal of Educational Technology*.

7. Shaik, I. A. (2023). Security applications of blockchain: Emerging research and innovations. *Journal of Cyber Security*.

8. Ceylan, O., & Işık, A. H. (2020). Blokzincir Teknolojisi ve Uygulama Alanları. *Bilişim Teknolojileri Dergisi*.

РАЗРАБОТКА МОДЕЛИ КЛАССИФИКАЦИИ ДЛЯ ПРОИЗВОДСТВЕННОГО ПРЕДПРИЯТИЯ НА ОСНОВЕ МЕТОДА "ДЕРЕВО РЕШЕНИЙ"

Баратзаде Р.И.,
Магистр
Азербайджанский государственный университет нефти и промышленности, г. Баку, Азербайджан
Салимов В.Г.
к.т.н., доцент
Азербайджанский государственный университет нефти и промышленности, г. Баку, Азербайджан

DEVELOPMENT OF A CLASSIFICATION MODEL FOR A MANUFACTURING ENTERPRISE BASED ON THE DECISION TREE METHOD

Baratzada R.
Master
Azerbaijan State University of Oil and Industry, Baky, Azerbaijan
Salimov V.
Ph.D., Associate Professor
Azerbaijan State University of Oil and Industry, Baky, Azerbaijan
DOI: 10.5281/zenodo.19828167

АННОТАЦИЯ

В условиях стремительного развития технологий и непрерывной трансформации промышленных систем поиск значимых закономерностей и скрытых знаний, выходящих за рамки традиционных методов анализа данных, приобретает все большее значение. Эта потребность играет важную роль в поддержке заинтересованных сторон, особенно в областях принятия оперативных решений, прогнозирования и управления производством. Для производственного предприятия своевременные и обоснованные решения имеют решающее значение для повышения производительности, обеспечения качества продукции, снижения рисков и поддержания устойчивого развития. Поэтому важно определить эффективные методы деревьев решений (ДР) для решения задач классификации и установить их практическую применимость в реальных производственных условиях. Интеграция крупномасштабной обработки данных с машинным обучением (МО) обеспечивает ценную основу для разработки моделей, основанных на данных, на промышленных предприятиях. В этом контексте настоящее исследование направлено на разработку методологического подхода к построению эффективной модели классификации для производственного предприятия на основе метода деревьев решений. Особое внимание уделяется выбору информативных признаков, формированию правил классификации и практической значимости построенной модели для принятия производственных решений. Используя аналитический потенциал машинного обучения и объединенные усилия исследователей, аналитиков данных и специалистов по производству, данное исследование стремится получить более точные, понятные и практически применимые результаты. В то же время важно понимать, что полезность модели классификации зависит не только от ее математической точности, но и от того, насколько четко ее результаты могут быть интерпретированы лицами, принимающими решения. В контексте управления производством модель должна оставаться доступной, понятной и пригодной для практического применения менеджерами и специалистами, непосредственно участвующими в производственных процессах. В этом отношении исследование подчеркивает интерпретируемость модели дерева решений и ее ценность как инструмента, способного поддерживать эффективный анализ, повышать качество принятия решений и способствовать общей эффективности и конкурентоспособности производственного предприятия.

ABSTRACT

In today's rapidly advancing technological environment and continuously transforming industrial systems, the search for meaningful patterns and hidden knowledge beyond traditional data analysis methods has become increasingly important. This need plays a significant role in supporting stakeholders, especially in the areas of operational decision-making, forecasting, and production management. For a manufacturing enterprise, timely and well-grounded decisions are essential for improving productivity, ensuring product quality, reducing risks, and maintaining sustainable development. Therefore, it is important to identify effective Decision Tree (DT) techniques for solving classification problems and to determine their practical applicability in real production conditions. The integration of large-scale data processing with Machine Learning (ML) provides a valuable basis for developing data-driven models in industrial enterprises. In this context, the present study aims to provide a methodological approach for building an efficient classification model for a manufacturing enterprise based on the Decision Tree method. Particular attention is given to the selection of informative features, the formation of classification rules, and the practical relevance of the constructed model for production decision-making. By using the analytical potential of machine learning and the combined efforts of researchers, data analysts, and production specialists, the study seeks to obtain more accurate, understandable, and practically applicable results. At the same time, it is important to recognize that the usefulness of a classification model depends not only on its mathematical

accuracy, but also on how clearly its results can be interpreted by decision-makers. In the context of industrial management, a model should remain accessible, comprehensible, and suitable for practical application by managers and specialists who are directly involved in production processes. In this regard, the study emphasizes the interpretability of the Decision Tree model and its value as a tool that can support effective analysis, improve decision-making quality, and contribute to the overall efficiency and competitiveness of the manufacturing enterprise.

Ключевые слова: Дерево решений; модель классификации; производственное предприятие; машинное обучение; управление производством.

Keywords: Decision tree; classification model; manufacturing enterprise; machine learning; production management.

ВВЕДЕНИЕ

В условиях стремительного роста объемов данных и усложнения производственных процессов традиционные подходы к анализу и принятию управленческих решений уже не всегда обеспечивают необходимую точность, оперативность и обоснованность. Для производственных предприятий особую значимость приобретает использование современных методов интеллектуального анализа данных, позволяющих выявлять скрытые закономерности, прогнозировать результаты и повышать эффективность управления. В связи с этим возрастает интерес к разработке моделей классификации, способных поддерживать принятие решений в различных функциональных областях производственной деятельности.

Одним из наиболее доступных и интерпретируемых методов машинного обучения является метод «дерево решений» [2]. Его применение позволяет не только классифицировать объекты на основе заданных признаков, но и представить результат анализа в наглядной и логически понятной форме. Это особенно важно для производственного предприятия, где принятие решений связано с множеством факторов, включая технологические параметры, производственные риски, качество продукции, ресурсообеспечение и организационные особенности [10]. Использование дерева решений дает возможность выявить наиболее значимые признаки, влияющие на принадлежность объекта к определенному классу, а также сформировать удобную для практического применения классификационную модель.

Актуальность данного исследования обусловлена необходимостью повышения качества управленческих решений на производственном предприятии на основе анализа данных и применения методов интеллектуальной обработки информации. Несмотря на широкое развитие методов машинного обучения, вопросы их адаптации к задачам классификации в производственной среде сохраняют научную и практическую значимость. В этой связи целью данной работы является разработка модели классификации для производственного предприятия на основе метода «дерево решений», а также определение факторов, оказывающих наибольшее влияние на результаты классификации. Практическая ценность исследования заключается в возможности использования полученной модели для повышения эффективности анализа производственных данных и совершенствования системы принятия решений [9].

МЕТОДОЛОГИЯ ИССЛЕДОВАНИЯ

В данном исследовании в качестве основного метода используется алгоритм «дерево решений», относящийся к методам машинного обучения и интеллектуального анализа данных. Данный алгоритм применяется для построения классификационной модели, позволяющей распределять объекты производственного предприятия по заранее определённым классам на основе значений выбранных признаков. Выбор метода «дерево решений» обусловлен его наглядностью, логической интерпретируемостью и возможностью выявления наиболее значимых факторов, влияющих на результат классификации [9].

Методология исследования включает несколько последовательных этапов. На первом этапе осуществляется сбор и формирование исходного массива данных, характеризующего деятельность производственного предприятия. На втором этапе проводится предварительная обработка данных, включающая проверку полноты информации, устранение пропусков, исправление некорректных значений и подготовку признаков к последующему анализу. Предварительная обработка данных рассматривается как важный этап, поскольку качество исходной информации непосредственно влияет на точность итоговой классификационной модели [8].

На следующем этапе строится классификационная модель на основе алгоритма «дерево решений». Данный алгоритм формирует древовидную структуру, в которой внутренние узлы отражают проверку отдельных признаков, ветви показывают возможные направления разделения, а конечные узлы соответствуют определённым классам. Такая структура позволяет определить, какие именно показатели оказывают наибольшее влияние на отнесение объекта к тому или иному классу, а также представить результаты анализа в наглядной и удобной для интерпретации форме.

Далее проводится обучение и тестирование построенной модели. В процессе оценки анализируется точность классификации, сопоставляются фактические и прогнозируемые результаты и определяется пригодность модели для практического применения в условиях производственного предприятия. На заключительном этапе выполняется интерпретация полученных результатов, позволяющая выявить ключевые факторы классификации и обосновать возможность использования модели в системе анализа и принятия управленческих решений.

ТЕОРИЯ И ВЫЧИСЛЕНИЯ

Теоретическая основа данного исследования связана с применением методов машинного обучения для решения задач классификации в условиях производственного предприятия. В рамках интеллектуального анализа данных классификация рассматривается как процесс отнесения объектов к заранее определённым классам на основе совокупности признаков, характеризующих их состояние, свойства или результаты функционирования. Для производственной среды такой подход имеет особое значение, поскольку позволяет систематизировать данные, выявлять устойчивые зависимости между показателями и использовать полученные результаты в целях повышения эффективности управления.

В данной работе в качестве основного инструмента классификации выбран метод «дерево решений». Теоретическая значимость данного метода заключается в том, что он формирует последовательную логическую структуру принятия решения, основанную на поэтапном разделении совокупности наблюдений по значениям наиболее информативных признаков. В отличие от более сложных алгоритмов, дерево решений обеспечивает не только получение итогового классификационного результата, но и позволяет интерпретировать сам механизм его формирования. Это особенно важно для производственного предприятия, где практическая применимость модели зависит не только от точности, но и от возможности объяснить, какие именно факторы оказывают определяющее влияние на принадлежность объекта к конкретному классу [1].

С вычислительной точки зрения построение модели классификации основывается на обработке исходного массива данных и последовательном выборе признаков, обеспечивающих наилучшее разделение объектов. На каждом шаге алгоритм оценивает возможные варианты разбиения и выбирает тот признак, который позволяет наиболее чётко разделить наблюдения по классам. В результате формируется древовидная структура, где корневой узел отражает наиболее значимый показатель, внутренние узлы представляют последующие условия разделения, а листовые вершины соответствуют конечным классам. Таким образом, вычислительный процесс переводит теоретическую модель классификации в практический инструмент анализа производственных данных.

Практическое развитие теоретической основы в исследовании выражается в применении алгоритма к данным производственного предприятия. На основе расчётов определяется, какие показатели оказывают наибольшее влияние на итог классификации, а также формируются правила, по которым объекты распределяются по соответствующим группам. Представление результатов в виде дерева и графической схемы позволяет визуально отразить последовательность вычислительных шагов, показать структуру классификации и сделать полученные выводы более понятными для практического использования. Это обеспечивает связь между теоретическими положениями метода и их прикладной реализацией в условиях конкретной исследовательской задачи [5].

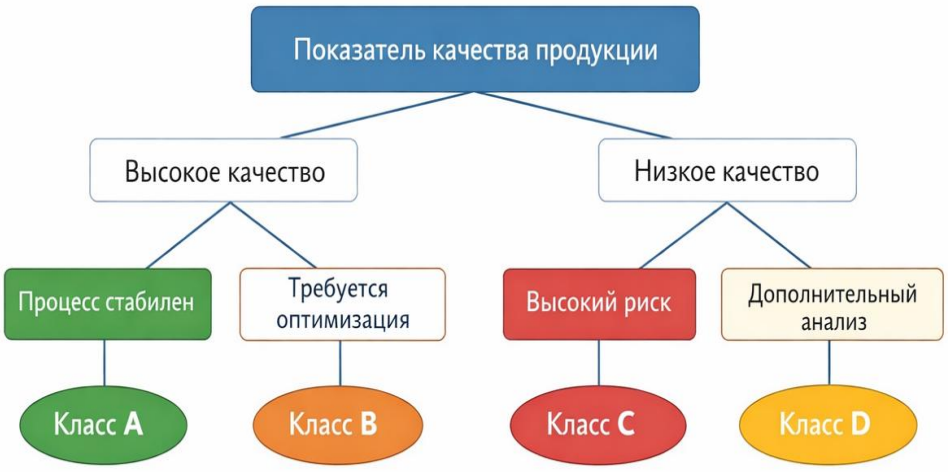


Рисунок 1. Структура классификационной модели для производственного предприятия на основе метода «дерево решений» [4]

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

Применение метода «дерево решений» в рамках данного исследования показало, что данный алгоритм является эффективным инструментом для построения классификационной модели на производственном предприятии. Одним из основных преимуществ метода является возможность достаточно просто прогнозировать принадлежность новых наблюдений к определённым классам на основе значений выбранных признаков. Процесс классификации осуществляется начиная с корневого узла дерева, где анализируется наиболее значимый показатель, после чего в зависимости от его значения переход выполняется по соответствующей ветви к следующему узлу или конечному классу [6].

Полученные результаты свидетельствуют о том, что дерево решений позволяет не только формировать классификационные правила, но и представлять их в понятной и логически структурированной форме. Это особенно важно в условиях производственного предприятия, где практическая ценность модели определяется не только точностью классификации, но и возможностью интерпретировать, какие именно факторы оказывают наибольшее влияние на итоговое распределение объектов по классам. В этом заключается прикладная значимость разработанной модели, так как она может быть использована в аналитической и управленческой деятельности предприятия [7].

Вместе с тем результаты исследования показывают, что использование дерева решений связано и с определёнными ограничениями. Незначительные изменения в исходных данных могут приводить к заметным изменениям в структуре дерева, что указывает на чувствительность данного алгоритма к характеристикам выборки. Кроме того, при работе с крупными массивами данных дерево может становиться чрезмерно разветвлённым, что затрудняет его интерпретацию и может снижать точность классификации новых наблюдений. Также следует учитывать, что данный метод не всегда является оптимальным для задач, в которых преобладают непрерывные переменные и сложные зависимости между признаками.

Обсуждение результатов позволяет отметить, что эффективность дерева решений в значительной степени зависит от качества исходных данных, корректности их предварительной обработки и обоснованности выбора признаков. Сложность и динамичность производственной среды, а также наличие большого числа взаимосвязанных факторов могут осложнять процесс построения устойчивой классификационной модели. В связи с этим особую важность приобретает этап валидации модели и проверка её пригодности для практического использования. Для обеспечения большей точности и устойчивости в дальнейшем целесообразно рассмотреть возможность применения более сложных прогностических моделей, способных адаптироваться к изменениям данных и учитывать сложные производственные зависимости.

Таблица 1.

Основные преимущества и ограничения метода «дерево решений» в задаче классификации производственных данных [8]

Преимущества метода	Ограничения метода
Наглядность модели	Чувствительность к изменениям данных
Простота интерпретации результатов	Возможность переобучения
Возможность работы с различными типами данных	Снижение точности при больших объемах данных
Быстрая классификация новых объектов	Сложность при наличии большого числа признаков
Поддержка принятия решений	Возможность нестабильной структуры дерева

Таким образом, результаты исследования подтверждают, что метод «дерево решений» может быть успешно использован для разработки классификационной модели производственного предприятия. Его основными достоинствами являются наглядность, логическая интерпретируемость и возможность выявления ключевых факторов классификации. Одновременно выявленные ограничения показывают необходимость осторожного применения данного метода и дальнейшего совершенствования модели с учётом специфики производственных данных.

ЗАКЛЮЧЕНИЕ

В результате проведённого исследования было установлено, что метод «дерево решений» может эффективно использоваться для разработки классификационной модели для производственного предприятия. Применение данного метода позволило рассмотреть задачу классификации как процесс последовательного анализа производственных признаков и выявления факторов, оказывающих наибольшее влияние на распределение объектов по заранее определённым классам. Основной результат исследования заключается в том, что дерево решений обеспечивает не только возможность классификации данных, но и позволяет представить сам процесс принятия решения в наглядной, логически структурированной и практически интерпретируемой форме. Это особенно важно в условиях производственного предприятия, где качество принимаемых решений напрямую связано с точностью анализа, своевременностью обработки информации и возможностью понятного объяснения полученных результатов. Значимость работы определяется тем, что разработанная модель может быть использована как инструмент поддержки управленческих

решений, связанных с оценкой состояния производственных объектов, анализом факторов эффективности и систематизацией данных предприятия. Актуальность исследования обусловлена возрастающей ролью интеллектуального анализа данных и методов машинного обучения в условиях цифровизации промышленности, когда предприятия нуждаются в доступных, понятных и одновременно результативных инструментах анализа. Практическая применимость исследования заключается в возможности использования предложенного подхода для повышения качества обработки производственной информации, выявления ключевых закономерностей и совершенствования механизмов аналитической поддержки управления. Вместе с тем исследование имеет определённые ограничения, связанные с зависимостью точности модели от качества исходных данных, полноты признакового пространства и устойчивости самой структуры дерева к изменениям выборки. Кроме того, при значительном увеличении объёма данных и числа переменных модель может становиться более сложной для интерпретации, что снижает одно из её главных преимуществ. По этой причине полученные результаты следует рассматривать как основу для дальнейшего развития исследования. В качестве рекомендации целесообразно отметить необходимость расширения набора анализируемых данных, проведения более глубокой проверки устойчивости модели и сравнительного применения других алгоритмов классификации. Это позволит повысить точность прогноза, усилить надёжность результатов и расширить возможности практического применения модели в системе управления производственным предприятием.

ОГРАНИЧЕНИЯ ИССЛЕДОВАНИЯ

Данное исследование имеет ряд ограничений, которые могут повлиять на интерпретацию полученных результатов. Прежде всего, точность классификационной модели на основе метода «дерево решений» зависит от качества исходных данных, полноты набора признаков и корректности предварительной обработки информации. Кроме того, при увеличении объема данных и числа переменных структура дерева может становиться более сложной, что снижает его интерпретируемость. Еще одним ограничением является то, что результаты исследования ориентированы на условия конкретной задачи классификации производственного предприятия и потому могут требовать дополнительной адаптации при применении в других производственных условиях.

Литература

1. Abedinia, A., & Seydi, V. (2024). Building semi-supervised decision trees with semi-cart algorithm. *International Journal of Machine Learning and Cybernetics, 15*, 4493–4510. https://doi.org/10.1007/s13042-024-02161-z
2. Aldinucci, T., & Lapucci, M. (2024). Loss-optimal classification trees: A generalized framework and the logistic case. *TOP, 32*, 323–350. https://doi.org/10.1007/s11750-024-00674-y
3. Chen, K.-S., Lin, S.-C., Lai, K.-K., & Wang, W.-P. (2023). Decision-making model of production data management for multi-quality characteristic products in consideration of Industry 4.0. *Applied Sciences, 13*(13), 7883. https://doi.org/10.3390/app13137883
4. Chen, S., Hao, J., Chen, Y., & Yang, Z. (2024). A decision tree-based method for evaluating the remanufacturability of used parts. *Processes, 12*(6), 1220. https://doi.org/10.3390/pr12061220
5. Hagag, A. M., Yousef, L. S., & Abdelmaguid, T. F. (2023). Multi-criteria decision-making for machine selection in manufacturing and construction: Recent trends. *Mathematics, 11*(3), 631. https://doi.org/10.3390/math11030631
6. Koulinas, G. K., Paraschos, P. D., & Koulouriotis, D. E. (2024). A machine learning framework for explainable knowledge mining and production, maintenance, and quality control optimization in flexible circular manufacturing systems. *Flexible Services and Manufacturing Journal, 36*, 737–759. https://doi.org/10.1007/s10696-024-09537-x
7. Md, A. Q., Jha, K., Haneef, S., Sivaraman, A. K., & Tee, K. F. (2022). A review on data-driven quality prediction in the production process with machine learning for Industry 4.0. *Processes, 10*(10), 1966. https://doi.org/10.3390/pr10101966
8. Patalas-Maliszewska, J., Łosyk, H., & Rehm, M. (2022). Decision-tree based methodology aid in assessing the sustainable development of a manufacturing company. *Sustainability, 14*(10), 6362. https://doi.org/10.3390/su14106362
9. Tercan, H., & Meisen, T. (2022). Machine learning and deep learning based predictive quality in manufacturing: A systematic review. *Journal of Intelligent Manufacturing, 33*, 1879–1905. https://doi.org/10.1007/s10845-022-01963-8
10. Tsou, C.-S., Liou, C., & Cheng, L. (2022). Quality prediction through machine learning for the inspection and manufacturing process of blood glucose test strips. *Cogent Engineering, 9*(1), Article 2083475. https://doi.org/10.1080/23311916.2022.2083475

INVESTIGATION OF OPTICAL TRANSMITTER AND RECEIVER SYSTEMS IN ARTIFICIAL INTELLIGENCE

Davrishova I.,
Hesenzade G.
Azerbaijan Technical University, Baku, Azerbaijan
DOI: 10.5281/zenodo.19828181

ABSTRACT

This paper comprehensively investigates the application of artificial intelligence technologies in optical transmitter and receiver systems, as well as their functional characteristics. The increasing demand for high-speed and reliable data transmission in modern telecommunication systems has further enhanced the importance of optical communication systems. These systems are characterized by high transmission speed and low signal loss, as they operate based on the principle of converting electrical signals into optical signals and transmitting them through optical fiber media.

The working principles of optical transmitter and receiver devices, along with their main components and technical characteristics, are analyzed in detail in this paper. At the same time, spectral errors that occur during signal transmission, including dispersion, noise, attenuation, and nonlinear effects, are examined, and their impact on the overall system performance is evaluated.

Particular attention is given to the application of artificial intelligence algorithms for signal processing, automatic error detection, and the optimization of system parameters. The use of machine learning and deep learning methods enables the improvement of signal quality, the reduction of transmission losses, and the implementation of adaptive system control.

Furthermore, simulation models of optical communication systems are developed in the study, and the system behavior is analyzed under various parameters. The simulation results demonstrate that the application of artificial intelligence-based approaches leads to an increase in the signal-to-noise ratio (SNR), a decrease in the bit error rate (BER), and an improvement in overall system stability.

In conclusion, the integration of artificial intelligence technologies into optical transmitter and receiver systems creates significant scientific and technological advancements in the field of communications and serves as one of the key directions in the development of next-generation communication systems.

Keywords: Artificial intelligence, optical communication, optical transmitter systems, optical receiver systems, spectral distortions, SNR (signal-to-noise ratio), BER (bit error rate).

Introduction.

In the modern era, the rapid development of information and communication technologies has significantly increased the demand for systems that ensure high-speed, reliable, and large-capacity data transmission. In particular, driven by digital transformation, cloud technologies, Big Data, and the development of 5G/6G networks, optical communication systems have become one of the key infrastructure components. Optical fiber technology is considered superior to conventional communication methods due to its wide bandwidth, low signal attenuation, and resistance to electromagnetic interference.

The core of optical communication systems consists of optical transmitter and receiver devices. The transmitter system converts electrical signals into optical signals and enables their transmission through the fiber-optic medium, while the receiver system captures these signals and converts them back into electrical form. However, during data transmission, the signal quality may deteriorate due to various physical and technical factors. These factors include dispersion, attenuation, noise, and nonlinear effects, which lead to spectral errors and negatively affect the overall system performance.

In recent years, the development of artificial intelligence technologies has created new opportunities for addressing these challenges. Through artificial intelligence, particularly machine learning and deep learning methods, it has become possible to automatically detect errors in complex signal environments, optimize signal processing, and adaptively adjust system parameters. This approach provides higher accuracy and efficiency compared to traditional methods.

Several international scientific studies have reported positive results regarding the integration of artificial intelligence into optical communication systems. For instance, in Optical Fiber Communications by Gerd Keiser, the fundamental principles of optical fiber communication and signal transmission errors are extensively explained. In addition, IEEE-published scientific articles emphasize that AI-based algorithms demonstrate high efficiency in signal processing and error reduction. These studies show that the application of artificial intelligence in optical systems is significant not only theoretically but also practically.

Furthermore, one of the modern research directions is the development and analysis of simulation models for optical communication systems. Through simulation, system behavior under various conditions is studied, the impact of spectral errors is evaluated, and the effectiveness of artificial intelligence algorithms is tested. This approach is considered an important tool for the design and optimization of real-world systems.

The aim of this article is to investigate both the theoretical and practical aspects of the application of artificial intelligence technologies in optical transmitter and receiver systems, analyze spectral errors and their mitigation methods, and evaluate system performance based on simulation results.

Literature Review.

The integration of optical communication systems and artificial intelligence technologies is considered one of the key directions of modern scientific research. Studies in this field show that the performance of optical transmitter and receiver systems depends directly on both the characteristics of the physical environment and the applied signal processing methods.

The theoretical foundations of optical communication systems have been extensively covered in many fundamental works. In particular, in Optical Fiber Communications by Gerd Keiser, the operating principles of optical fiber technology, as well as factors such as transmission losses and dispersion, are explained in detail. This work is considered an important source for understanding the main characteristics of optical systems and the factors affecting their performance.

Research on the application of artificial intelligence in optical communication systems has become increasingly intensive in recent years. Scientific articles published by IEEE indicate that machine learning and deep learning methods demonstrate high efficiency in signal processing, error detection, and system optimization. These studies highlight the adaptive decision-making capability of artificial intelligence in complex signal environments.

In local literature, the theoretical and practical foundations of optoelectronic systems are extensively presented in the book Optoelectronic and Quantum Devices and Instruments by Irada Davrishova. This work provides a detailed explanation of the structure and operating principles of optical transmitter and receiver devices, the characteristics of components such as lasers and photodiodes, as well as the role of quantum effects in optoelectronic systems.

In addition, several studies have focused on the analysis of spectral errors. The impact of factors such as dispersion, attenuation, and noise on signal quality has been investigated using various models and analytical methods. In this context, Fourier analysis, signal-to-noise ratio (SNR), and bit error rate (BER) are commonly used as key evaluation metrics.

Recent studies show that artificial intelligence-based approaches provide more effective results in compensating spectral errors and optimizing system performance. In particular, neural networks and deep learning models enable the detection of signal distortions and allow real-time corrections. This, in turn, increases the reliability and efficiency of optical communication systems.

Thus, the analysis of the existing literature indicates that the study of optical transmitter and receiver systems based on artificial intelligence is both a relevant and promising research direction from theoretical and practical perspectives. A comparative analysis of local and international sources creates broad opportunities for the development of more efficient models and technologies in this field.

Data and Preliminary Analysis.

In this study, the operating principles of optical transmitter and receiver systems and their performance indicators have been analyzed. During the investigation, particular attention was focused on spectral errors arising in the signal transmission process and their impact on the system.

Preliminary analysis shows that signal quality depends on factors such as transmission distance, noise level, and dispersion. As the distance increases, the signal becomes weaker and distorted, which leads to data loss.

At the same time, the signal-to-noise ratio (SNR) and bit error rate (BER) have been identified as the main evaluation metrics of the system. With the application of artificial intelligence algorithms, it is possible to optimize these parameters and reduce errors.

Figure 1 illustrates the general structure of the optical communication system. The system consists of a transmitter, a transmission medium (optical fiber), and a receiver. The transmitter converts the electrical signal into an optical signal and transmits it through the fiber, while the receiver captures this signal and converts it back into electrical form. This structure forms the basis of the communication process.

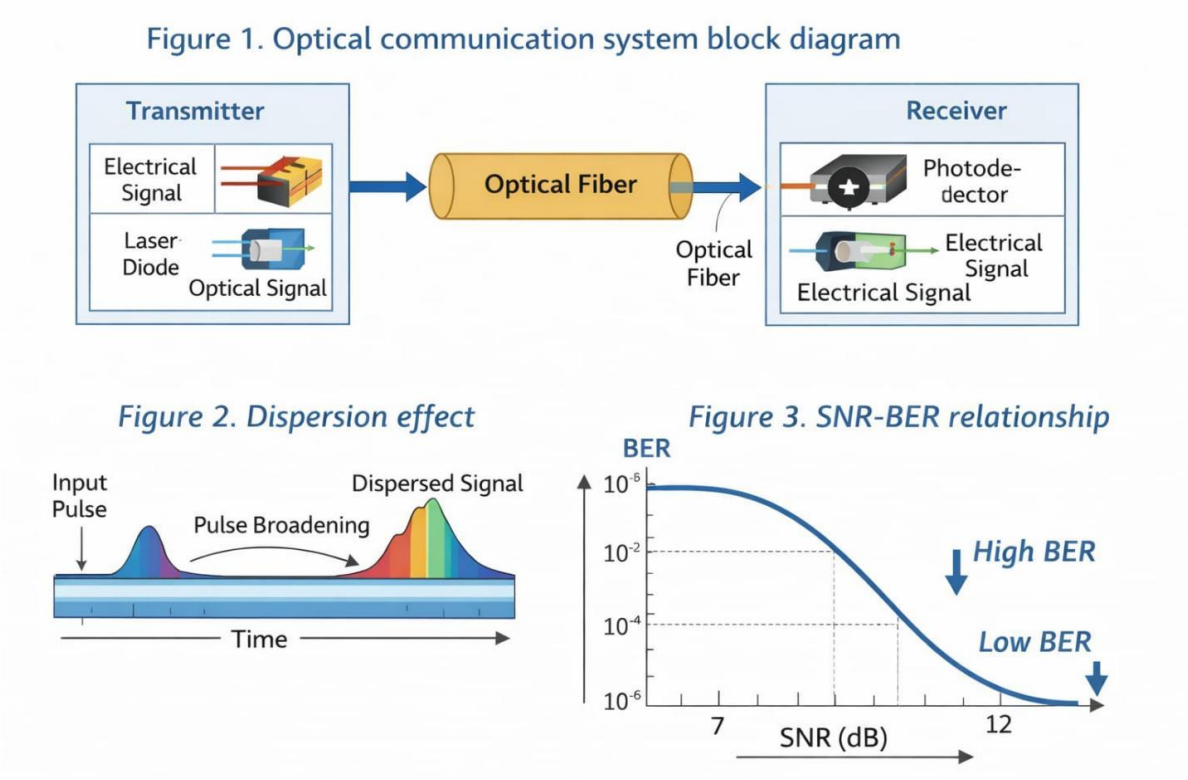


Figure 1. Block diagram of the optical communication system

In Figure 2, the broadening of a pulse due to the effect of dispersion during signal transmission is illustrated. As the signal propagates along the optical fiber, its shape changes and becomes wider. This phenomenon causes signal overlap, which makes accurate data reception more difficult.

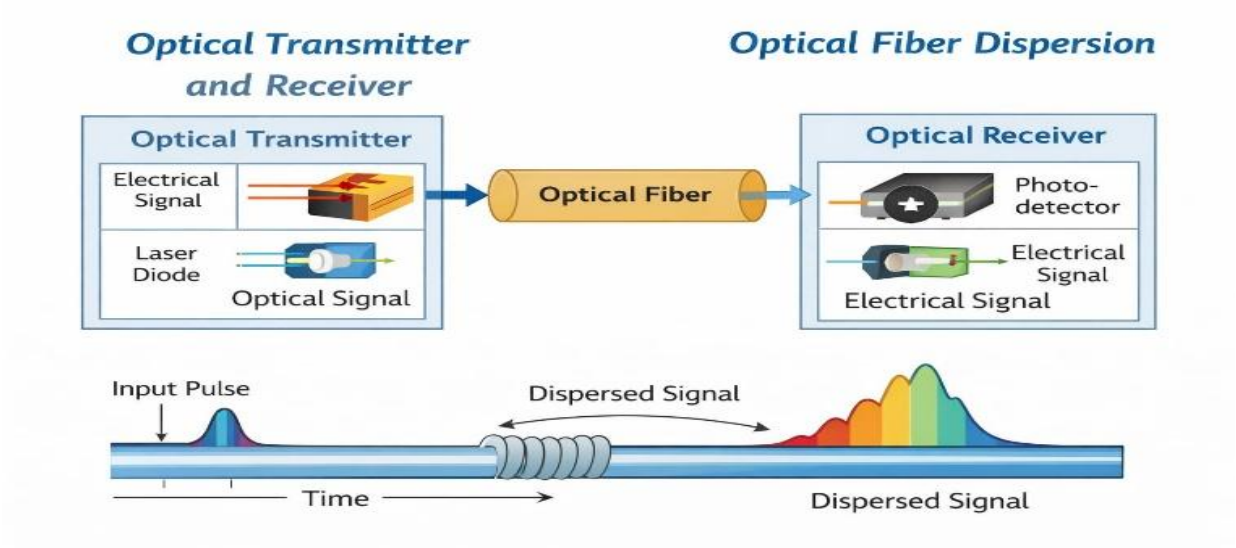


Figure 2. Dispersion effect

In Figure 3, the graph shows the relationship between the signal-to-noise ratio (SNR) and the bit error rate (BER). As can be seen from the graph, as SNR increases, BER decreases, meaning that the signal quality improves. These parameters play a key role in evaluating the efficiency of communication systems.

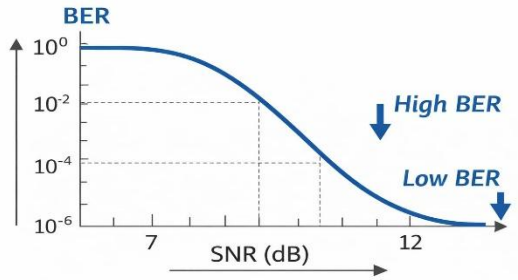


Figure 3. Relationship between SNR and BER

Overall, the preliminary analysis shows that the signal quality in optical communication systems mainly depends on factors such as noise, dispersion, and transmission distance. The figures clearly illustrate the signal transmission process, the causes of signal distortion, and the inverse relationship between SNR and BER. As a result, the application of artificial intelligence plays a significant role in reducing these errors and optimizing system performance.

Methodology

This study is based on the theoretical modeling and performance analysis of artificial intelligence-based optical transmitter and receiver systems. A signal transmission model has been developed by taking into account the physical effects of the optical channel, including attenuation, dispersion, noise, and nonlinearity.

Artificial intelligence-based approaches have been theoretically applied for signal recovery and channel optimization. The system performance has been evaluated using metrics such as bit error rate (BER), signal-to-noise ratio (SNR), and channel capacity.

1. Optical Channel model

$$y(t) = x(t) \cdot h(t) + n(t)$$

$y(t)$– output (received) signal
$x(t)$ –transmitted signal
$h(t)$– channel impulse response
$n(t)$– noise

2. Signal Attenuation

$$P(L) = P_0 e^{-\alpha L}$$

$P(L)$– signal power at distance L
P_0– initial power
e – base of natural logarithm
α– attenuation coefficient
L – transmission distance

3. Signal-to-noise ratio (SNR)

$$SNR = \frac{P_s}{P_n}$$

SNR – Signal-to-noise ratio
P_s– Signal power
P_n– Noise power

4. Bit Error Rate (BER)

$$\text{BER} = \frac{N_{error}}{N_{total}}$$

BER– bit error rate
N_{error} – number of erroneous bits
N_{total}– total number of transmitted bits

5. **Dispersion effect**

$$\Delta t = D \cdot L \cdot \Delta\lambda$$

Δt – temporal broadening of the pulse
D – dispersion coefficient
L – fiber length
$\Delta\lambda$ –wavelength spread

6. **Kerr nonlinear effect**

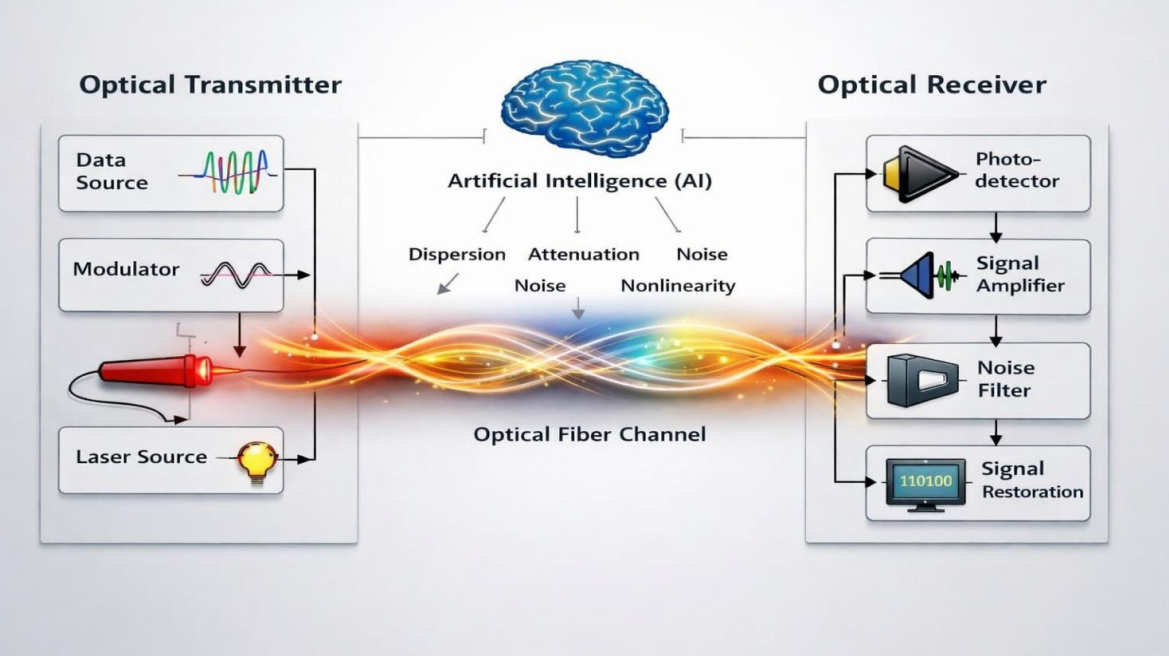
$$n = n_0 + n_2 I$$

n – total refractive index
n_0 – linear refractive index
n_2 –nonlinear coefficient
I – Light intensity

Analysis and Interpretation of Results

The theoretical analysis and modeling results indicate a significant improvement in the performance of artificial intelligence-based optical transmitter and receiver systems. Based on the obtained results, the increase in the SNR value and the decrease in the BER confirm that the system operates with higher quality. Partial compensation of dispersion and nonlinear effects using artificial intelligence approaches improves signal stability. In addition, the increase in Shannon channel capacity indicates higher data transmission efficiency. Overall, the results confirm that AI-based methods play an effective role in optimizing optical communication systems.

Optical fiber communication system (optical transmission scheme)



This diagram illustrates the general structure of an optical communication system and consists of three main parts: the optical transmitter, the optical channel, and the optical receiver. On the left side, an electrical signal generated by the information source and modulator is converted into an optical signal and transmitted using a laser source. In the central part of the optical fiber channel, the signal is affected by dispersion, attenuation, noise, and nonlinear effects.

The artificial intelligence (AI) block shown at the top of the scheme intervenes in these processes to optimize the signal, particularly by performing functions such as dispersion compensation, noise reduction, and correction of nonlinear distortions. On the right side, the optical receiver section is located, where the photodetector converts the optical signal back into an electrical signal, followed by amplification, filtering, and signal recovery stages.

Overall, the scheme visually demonstrates that artificial intelligence plays an important role in improving signal quality in optical communication systems at both the transmission and reception stages.

Conclusion

The results of this study indicate that the efficiency of optical transmitter and receiver systems mainly depends on dispersion, noise, attenuation, and nonlinear effects occurring during signal transmission. The developed theoretical models and preliminary analyses show that these factors degrade signal quality and negatively affect overall system performance. Parameters such as SNR, BER, and Shannon channel capacity serve as key metrics for evaluating system performance.

The applied methodology and analyses demonstrate that artificial intelligence algorithms play a significant role in mitigating these issues. In particular, machine learning and deep learning methods make signal recovery, error detection, and system parameter optimization more effective. As a result, the signal-to-noise ratio increases, the bit error rate decreases, and system stability improves.

Furthermore, optical channel modeling and the application of AI-based approaches enable improved data transmission efficiency and adaptive system control. Overall, the obtained results show that the integration of artificial intelligence into optical communication systems provides significant advantages both theoretically and practically and represents one of the key directions in the development of next-generation high-speed communication technologies.

References

1. Keiser, G. Optical Fiber Communications. McGraw-Hill, 2010.
2. Agrawal, G. P. Fiber-Optic Communication Systems. Wiley, 2012.Govind P. Agrawal. Nonlinear Fiber Optics. Academic Press, 2013.
3. Proakis, J. G., Salehi, M. Digital Communications. McGraw-Hill, 2008.
4. Haykin, S. Neural Networks and Learning Machines. Pearson, 2009.
5. Goodfellow, I., Bengio, Y., Courville, A. Deep Learning. MIT Press, 2016.
6. Ramaswami, R., Sivarajan, K. N. Optical Networks: A Practical Perspective. Morgan Kaufmann, 2009.
7. Ellis, A. D., Zhao, J., Cotter, D. “Approaching the Nonlinear Shannon Limit.” Journal of Lightwave Technology, 2010.
8. Winzer, P. J. “High-Spectral-Efficiency Optical Modulation Formats.” Journal of Lightwave Technology, 2012.
9. IEEE Communications Society. “Applications of Machine Learning in Optical Networks.” IEEE Journals, 2019.
10. İradə Dəvrişova. Optoelektron və kvant cihazları və qurğuları. Bakı, 2014.
11. Bishop, C. M. Pattern Recognition and Machine Learning. Springer, 2006.

ИССЛЕДОВАНИЕ И ОПТИМИЗАЦИЯ СОСТАВА И СВОЙСТВ ДЕКОРАТИВНЫХ ЦЕМЕНТНЫХ КОМПОЗИЦИЙ С ДОБАВКОЙ ТРАВЕРТИНА (РАКУШЕЧНИКА)

Болотов Т.Т.
Кыргызский государственный технический университет им. И. Раззакова
г. Бишкек, к.т.н., доцент
Абдусаматов К.Б.
Джизакский политехнический институт
г. Джизак, PhD, доцент
Улан уулу Б.
Кыргызский государственный технический университет им. И. Раззакова
г. Бишкек, магистрант

INVESTIGATION AND OPTIMIZATION OF THE COMPOSITION AND PROPERTIES OF DECORATIVE CEMENT COMPOSITIONS WITH THE ADDITION OF TRAVERTINE (SEASHELL)

Bolotov T.
Kyrgyz State Technical University named after I. Razzakov Bishkek,
Candidate of Technical Sciences, Associate Professor
Abdusamatov K.B.
Jizzakh Polytechnic Institute
PhD, Associate Professor
Ulan uulu B.
Kyrgyz State Technical University named after I. Razzakov Bishkek,
Master's student
DOI: 10.5281/zenodo.19828192

АННОТАЦИЯ

В статье приведены результаты исследования (оптимизаций) цементных композиций оптимального состава с использованием Сары Ташского месторождения измельченного травертина. Приведены результаты исследования гранулометрического состава и физико-механические характеристики декоративных цементных композиций различных составов: цемент - травертина, прошедших совместную механоактивацию в лабораторной мельнице.

Разработаны и оптимизированы составы декоративных цементных композиций с широким спектром применения.

ABSTRACT

The article presents the results of a study on the optimization of cement composites with an optimal composition using ground travertine from the Sary-Tash deposit. The granulometric composition and physical-mechanical properties of decorative cement composites of various formulations-cement-travertine systems subjected to joint mechanoactivation in a laboratory mill-are reported. Optimized formulations of decorative cement composites with a wide range of applications have been developed.

Ключевые слова: цементные композиции, композиционное вяжущее, вяжущее низкой водопотребности, клинкер, цемент, гипс, наполнитель, суперпластификатор, свойства.

Keywords: cement composites, composite binder, low water-demand binder, clinker, cement, gypsum, filler, superplasticizer, properties.

Введение:

Одним из приоритетных направлений развития цементной промышленности, удовлетворяющим принципам энерго- и ресурсосбережения является создание цементных композиций с использованием минеральных добавок – наполнителей из местного сырья [1-3]. Среди последних большое внимание в кругах как зарубежных, так и отечественных ученых привлекают термоактивированные полиминеральные глины отдельно [4-8] или в сочетании с известняковой мукой [9-10].

Портландцементные композиции с минеральными добавками один из наиболее эффективных и простых путей осуществления концепции устойчивого («sustainable») развития цементной промышленности и строительной индустрии в целом. Однако, в настоящие время в Кыргызстане среднее содержание минеральных добавок в портландцементах составляет до 20 % [1-2].

Применение травертина Сары Ташского месторождения в качестве минерального наполнителя в цементной композиции позволяет экономить дорогостоящий портландцемент, при этом увеличивая прочностные характеристики цементной композиции.

Травертин характеризуется светлой окраской и легкой размалываемостью, по химико-минералогическому составу характеризуется сродством к цементным минералам, поэтому значительный интерес представляет разработка оптимальных составов смешанных декоративных цементных композиций.

Результаты:

Для изготовления декоративных цементных композиций за основу использовали обыкновенный серый портландцемент М400 Д20, измельченную породу - травертина Сары-Ташского месторождения размером менее 0,16 мм, количество вводимого травертина в состав цементных композиций изменялись от 20 до 40 % от массы портландцемента. Для модифицирования физико-механических характеристик вводили до 1 % глиниума. Результаты исследований приведены в табл. 1.

Анализ проведенных исследований показывает, что использование травертина-ракушечниковой муки в качестве наполнителя в цемент несколько удлиняет начало схватывания цемента, а конец схватывания значительно ускоряется. Введение глиниума до 1 % в составы цементных композиций значительно ускоряет схватывание цементов, что указывает на структурообразующую роль добавки - глиниум.

Таблица 1

Результаты исследовании физико-механических характеристик цементных композиций

№ п/п	Состав смеси			НГ, %	Сроки схватывания		Предел прочности, МПа				КО
							ТВО		через 28 сут		
	портландцемент	травертин (ракушечник)	глиниум		начало	конец	Rизг	Rсж	Rизг	Rсж	
1	100	-	-	24	1ч 15 мин	7ч 05мин	3,80	16,18	6,15	26,44	51
2	80	20	-	25	2ч 20 мин	4ч 37мин	3,85	13,60	3,8	29,20	57
3	79	20	1	25	1 ч 27 мин	3ч 58мин	4,23	17,90	6,7	34,10	59
4	60	40	-	30	2 ч 6 мин	4ч 59мин	2,43	11,15	3,5	27,20	65
5	59	40	1	24	1ч 59 мин	3ч 58мин	3,54	12,72	6,1	33,28	67

При введении в цемент от 20 до 40 % добавки нормальная густота увеличивается до 28-30 %. В предыдущих наших исследованиях и трудах других исследований отмечается пластифицирующее воздействие тонкоизмельченного кальцита на портландцемент при использовании плотного известняка. В экспериментальных исследованиях не наблюдается пластифицирующего эффекта.

Во-первых, травертин (ракушечник) характеризуется повышенной измельчаемой способностью. При измельчении в течении одного часа продукт достигает тонкостью помола, соответствующей полному прохождению через сито 0,16. При получении смешанных вяжущих цемент с добавкой подвергался совместному доизмельчению короткий промежуток времени для гомогенизации смеси. Тонкость помола при этом составляла 8-10 % остатка на сите 008, что отвечает требованиям ГОСТ 10178-85. При этом травертин (ракушечник) равномерно распределяется в цементной композиции и превалирующее количество их составляют частички размером 005 мм, что видно из табл. 2.

Частички травертина (ракушечники) характеризовались повышенной развитой поверхностью, что и способствует повышению водопотребности смешанных цементных композиций.

Глиниум оказывает пластифицирующее действие на смесь и водопотребность смеси снижается. При этом значительно повышается прочность при сжатии и изгибе ($R_{изг}$ и $R_{сж}$) при твердении в нормальных условиях.

Образцы, цементных композиций подвергаемые тепловлажностной обработке характеризуются прочностью на сжатие, соответствующей 70 % прочности 28- суточного нормального твердения.

Установлено, что при использовании в качестве наполнителя в цементной композиций травертины от 20 до 40 % повышается прочность на сжатие на 26-28 % при твердении в нормальных условиях. Прочность на изгиб остается в пределах прочности исходного портландцемента (6,1 МПа).

Основной характеристикой белых цементов является коэффициент отражения вяжущих (характеристика белизны цемента по отношению к $CaSO_4$).

$КО_I$ (коэффициент отражения) цементных композиций с содержанием 20 % добавки составляет 55 %; а $КО_{II}$ с 40 % травертина (ракушечника) – 65-67 %, т.е. улучшается разбеливающий эффект добавки на портландцемент. Образцы смешанных цементных композиций с содержанием 40 % травертина (ракушечника) характеризуются КО = 65 - 67 %, что соответствует по белизне белым цементам III сорта, и их можно использовать для отделочных работ в строительстве жилых и общественных зданий.

В целях снижения расхода клинкера, повышения эффекта разбеливания и модификации свойств в составы смешанных цементных композиций вводили по 5 % извести с гипсом (сост. 3 и 4).

Состав 3 характеризуется достаточной прочностью 21,4 МПа, однако она несколько снижается

чем прочность портландцемента (на 18-20 %) при нормальном твердении.

При совместном тонком домалывании портландцемента, травертина и гипса с известью в процессе гидратации образуются основные соли сульфатогидрокальция типа $Ca(OH)_2 \cdot SO_4 \cdot H_2O$, которые способствуют при контакте с гипсом повышению прочности гипсового камня за счет протекания поликонденсационных процессов с частицами гипса: $CaSO_4 \cdot 2H_2O + CaO \rightarrow Ca(OH)_2 \cdot SO_4 \cdot H_2O$

Цементы 3, 4 относятся к быстросхватывающимся вяжущим: начало 13, 14 мин; конец 21-29 мин. эти вяжущие могут быть использованы для получения изделий без тепло- влажностной обработки (за счет ускоренного твердения и повышенной прочности в нормальных условиях твердения).

Таблица 2

Состав цементных композиций с использованием травертина (ракушечника)

№ п/п	Наимен. состава	НГ, %	Тонк. помола, %	Сроки схватывания		Предел прочности, МПа			
				начало	конец	ТВО		Через 28 сут	
						Rизг	Rсж	Rизг	Rсж
1	Ц - 80 % И -10 % С/Т – 10 %	28 %	проходит через сито 0,16 8-10 %	12 мин.	1 ч 18 мин.	3,8	10,9	3,8	17,8
2	Ц - 70 % И – 10 % С/Т - 20 %	28 %		28 мин.	1 ч 39 мин	3,2	9,08	3,4	16,6
3	Ц - 80 % И - 5 % С/Т – 10 % Г - 5 %	28 %		13 мин.	29 мин	3,4	13,1	4,2	21,4
4	Ц-70 % И – 5 % С/Т-20 % Г - 5 %	28 %		14 мин.	21 мин	3,0	9,9	3,2	16,5
5	Ц	24 %	ост. на сите 008 14 %	1 ч 15 мин	7 ч 0,5 мин	3,8	16,18	6,15	26,44

В состав 1 измельченный наполнитель травертин (ракушечник) вводится 10 % совместно с 10 % негашенной извести, а в состав 2- измельченный наполнитель травертин (ракушечник) - 20 %, негашенной извести 10 %.

В обоих составах отмечается ускорение сроков схватывания. По нашему мнению, это связано с поверхностной активностью добавки травертина (ракушечника), которая способствует интенсивной адсорбции раствора извести. Гидратация извести связана с выделением тепла, что также способствует ускорению протекания химических реакций гидратации клинкерных минералов. Причем, при реакции с алюмосодержащими фазами основным продуктом гидратации является гидрокарбоалюминат кальция (ГКАК) $C_3A \cdot CaCO_3 \cdot 11H_2O$. возможно образование $C_3A \cdot CaCO_3$ и $C_3A \cdot Ca(OH)_2$, контакты срастания $CaCO_3$ и $Ca(OH)_2$ отмечаются во многих работах, характеризующих гидратацию цемента в присутствии карбонатов - травертина.

Декоративные цементные композиции составов 1, 2 отличаются только содержанием извести до 10 % и «Сары-Таша» 10-20 %. Составы цементных композиции характеризуется сроком: начало схватывания 12 - 28 мин; конец 1 ч 18 мин. до 1 ч 39 мин. прочностью (17,8 и 16,6 МПа) за счет присутствия избыточного количества извести.

Выводы:

- На основе портландцемента с добавкой до 40 % травертина (ракушечника) получены декоративные цементные композиции, характеризующиеся белизной соответствующие белизне III сорта белого портландцемента (БПЦ) М 300.

- Установлено, что совместное использование пластифицирующей добавки (глиниума до 1 %) и тонкоизмельченного травертина (ракушечника) до 20-40 % способствует повышению прочности декоративных цементных композиции, при твердении в нормальных условиях.

- Прочность на сжатие цементных композиции с использованием измельченного травертина (ракушечника) несколько повышается, чем бездобавочных цементов, что можно объяснить более полной гидратацией клинкерных минералов.

- Разработаны и оптимизированы составы декоративных цементных композиции с использованием травертин (ракушечника) и модифицирующих добавок, характеризующиеся ускоренными сроками твердения.

Литература

1. Абдыкалыков А.А. Экспериментально-теоретические основы оптимизации реологических и прочностных свойств наполненных композиционных строительных материалов. Бишкек: Технология, 200-252 с.

2. Мавлянов А.С., Абдыкалыков А.А., Ассакунова Б.Т. Комплексное использование минерального сырья- Бишкек: НАН КР, Илим, 2016 – 326 с. ISBN 978-9967-12-599-5

3. Abdykalykov, A., Bolotov, T., Kurbanbaev, A., Matyeva, A., & Zhumabaev, R. (2024). Optimisation of composition and strength properties of slag-alkali binders based on fuel slags. *Architectural Studies*, 10(1), 125-135. doi: 10.56318/as/1.2024.125.

4. Abdykalykov, A., Bolotov, T., Kurbanbaev, A., Matyeva, A., S. Melibaev (2025) Optimisation of the composition and properties of decorative columns and arches using travertine Architectural Studies, 11(2) 2 (doi: 10.56318/as/2.2025.09.), 9-20.

5. Б.Т. Ассакунова, Т.Т. Болотов, И.К. Омурбеков Совместное воздействие карбонатной муки и пластифицирующих добавок на свойство бетона. Вестник Кыргызского государственного университета строительства, транспорта и архитектуры им. Н. Исанова 2017, №3, стр.147-150.

6. Скобло Л. И. Цементная промышленность на постсоветском пространстве -сегодня: взгляд изнутри // Цемент и его применение. 2016. № 1. С. 28-29.

7. Ермилова Е. Ю., Камалова З. А., Рахимов Р. З., Стоянов О. В., Хантимиров А. Г., Габбасов Д. А., Ахтариев Р. Р. Исследование влияния скорости подъема температуры при термоактивации глин на их пуццолановую активность // Ремонт. Восстановление. Модернизация. 2017. № 4. С. 25-27.

8. Proceedings: Proc. XIV International Congress on the Chemistry of cement, Beijing, China, 2015. Vol. I. 704 p.

9. Ермилова Е. Ю., Камалова З. А., Рахимов Р. З., Стоянов О. В., Савинков С. А. Термически-активированная глина как альтернативная замена метакаолина в композиционных портландцементах // Вестник Казанского технологического университета. 2015. т. 18. № 4. С. 175-179.

10. Ludwig H.-M. CO2-arme Zemente furnachhaltige Betone // Ibausil 16-19 September 2015. Weimar. Deutschland. 2015. Band 2. P. 7-32.

11. Скибстед И., Даи З., Расмуссен К. Е., Гарг Н. Термическая активация и пуццолановая активность кальцинированных глин для использования в портландцементах с добавками // Цемент и его применение. 2016. № 1. С. 144-151.

12. Ермилова Е. Ю., Камалова З. А., Рахимов Р.З., Гуляева Р.И. Исследование влияния комплексных добавок на основе карбонатных пород и термоактивированной полиминеральной глины на состав продуктов гидратации композиционного цементного камня // Известия КГАСУ. 2017. № 1 (39). С. 198-205.

13. 10. Стеенберг М., Херфорт Д., Поульсен С. Л., Скибстед И., Дамтофт И. С. Композиционный цемент на основе портландцемента, известняка и прокаленной глины // Цемент и его применение. 2014. № 5. С. 44-49.

14. Буланов П. Е., Гимазов А. Р., Замалиев И. Р., Вдовин Е. А., Мавлиев Л. Ф. Влияние содержания портландцемента на свойства укрепленных глинистых грунтов различного минералогического состава // Вестник Казанского технологического университета. 2017. № 9. С. 24-27.

15. Antoni M., Rossen J., Martirena F., Scrivener K. Cement substitution by a combination of metakaolin and limestone // Cement and Concrete Research. 2012. Vol. 42. P. 1579-1589.

16. Dhir K., Limbachiya M. C., McCarthy M. J., Chaipanich A. Evaluation of Portland limestone cements for use in concrete construction // Materials and Structures. 2007. Vol. 40. Iss. 5. P. 459-473.

17. Макарова И. А., Лохова Н. А. Физико-химические методы исследования строительных материалов. Братск: БГУ, 2011. 139 с.

18. Schulze S.E., Pierkes R., Rickert J. Optimization of cements with calcined clays as 6supplementary cementitious materials // The 14th International Congress on the Chemistry of Cement (ICCC 2015) during 13~16 October 2015, Beijing, China. - P. 693.

19. M. Antoni, J. Rossen, F. Martirena, K. Scrivener. Cement substitution by a combination of metakaolin and limestone// Cement and Concrete Research. 2012. Vol.42. P. 15791589.

ТЕОРЕТИЧЕСКИЕ ПРЕДПОСЫЛКИ ПО ОБЪЕДИНЕНИЮ ПРОЦЕССОВ ПРИ СОЗДАНИИ ПРИДОРОЖНОГО СЕРВИСНОГО ОБЪЕКТА

Султан Е.Ж.
Казахский автомобильно-дорожный институт им. Л.Б. Гончарова, Алматы
магистрант
Киялбай С.Н.
Казахский автомобильно-дорожный институт им. Л.Б. Гончарова
к.т.н., ассоциированный профессор кафедры
«Транспортное строительство и урбанистика», Алматы

THEORETICAL PREREQUISITES FOR THE COMBINATION OF PROCESSES IN THE CREATION OF A ROADSIDE SERVICE FACILITY

Sultan Y.,
Master's student
Kazakh Automobile and Road Institute named after L.B. Goncharov, Almaty
Kiyalbay S.
Kazakh Automobile and Road Institute named after L.B. Goncharov
Candidate of Technical Sciences, Associate Professor
of the Department of Transport Construction and Urban Studies, Almaty
DOI: 10.5281/zenodo.19828261

АННОТАЦИЯ

В статье рассматриваются теоретические предпосылки объединения процессов при создании придорожных сервисных объектов в условиях развития транспортной инфраструктуры стран СНГ, в том числе Республики Казахстан. Проанализированы особенности финансирования дорожной отрасли с использованием механизмов государственно-частного партнерства, позволяющих повысить эффективность взаимодействия государства и бизнеса. Обоснована роль качества транспортного сервиса как ключевого фактора формирования спроса на транспортные услуги. Раскрыта сущность транспортного обслуживания как комплексной системы, включающей процессы перемещения пассажиров и грузов и предоставления сопутствующих услуг. Рассмотрено влияние уровня автомобилизации населения на развитие придорожной инфраструктуры. Определены основные методологические подходы к размещению сервисных объектов, включая системный, проектно-интегрированный и организационно-технический подходы. Установлено, что плотность автомобильных дорог является одним из определяющих факторов формирования придорожного сервиса.

ABSTRACT

The article discusses the theoretical prerequisites for combining processes in the creation of roadside service facilities in the context of the development of transport infrastructure in the CIS countries, including the Republic of Kazakhstan. The article analyzes the specifics of financing the road industry using public-private partnership mechanisms, which make it possible to increase the effectiveness of government-business cooperation. The role of the quality of transport services as a key factor in the formation of demand for transport services is substantiated. The essence of transport services is revealed as an integrated system that includes the processes of moving passengers and cargo and providing related services. The influence of the level of motorization of the population on the development of roadside infrastructure is considered. The main methodological approaches to the placement of service facilities, including systemic, design-integrated, and organizational-technical approaches, are defined. It has been established that the density of highways is one of the determining factors in the formation of roadside services.

Ключевые слова: придорожный сервис, транспортная инфраструктура, транспортное обслуживание, бизнес-процессы, сервисные объекты, дорожная сеть.

Keywords: roadside service, transport infrastructure, transportation services, business processes, service facilities, road network.

В настоящее время в странах СНГ, в т.ч. и в Казахстане, финансирование строительства объектов инфраструктуры автомобильного транспорта и дорожной отрасли производится, как за счет государственных бюджетных ассигнований, так и за счет средств частного сектора. Таким образом, при использовании механизма ГЧП появляется возможность повышения эффективности взаимовыгодного сотрудничества государства и частного сектора, повышения качества предоставляемых услуг, ускоренной модернизации инфраструктуры, необходимой для диверсификации экономики.

Таким образом, в условиях современной конкурентной борьбы уровень спроса на транспортные услуги определяется, прежде всего, качеством сервиса. Для получения необходимого эффекта требуется решение комплекса задач по повышению уровня транспортных услуг, предоставляемых грузовладельцам и пассажирам.

Транспортное обслуживание (сервис) связано с процессом перемещения пассажиров и грузов в пространстве и во времени и предоставлением сопутствующих этой деятельности транспортных услуг. При этом персонал автосервисного предприятия посредством осязаемых дополняющих услугу материальных товаров удовлетворяет потребности потребителей. По мнению автоперевозчиков, транспортное обслуживание (сервис) можно определить как деятельность, связанную с процессом перемещения пассажиров и грузов в пространстве и во времени и предоставлением сопутствующих этой деятельности транспортных услуг. В качестве источника информации выступает база данных «World Road Statistics», которая обновляется ежегодно [1,2].

Практически во всех странах мира уровень автомобилизации населения считается одним из важных показателей благосостояния населения и организации создания придорожных сервисных услуг [3]: чем выше уровень благосостояния людей, тем больше вероятность приобретения ими автомобилей и создания сервисных услуг. Повышение уровня автомобилизации населения приводит к значительному изменению общественной, т.е. придорожной, инфраструктуры, уровень мобильности людей и улучшению экономического положения населения страны.

Методологической базой для размещения сервисных объектов на притрассовой полосе автомобильных дорог являются:

- системный подход для выбора параметров сервисных объектов;
- базовые принципы стандарта ISO 2001, рассматривающие расположение придорожных сервисных объектов как интегратор частного бизнеса, т.е. системы бизнес-процессов в рамках государственно-частного партнерства (ГЧП);
- проектно-интегрированный подход, рассматривающий бизнес-процессы придорожного сервис-менеджмента, как совокупность векторов интеграции в горизонтальной и вертикальной проекциях на концептуально-организационном, технологическом и финансовом уровнях;
- организационная концепция технического уровня, предусма-тривающая оптимальное расположение сервисных объектов на придорожной полосе автомобильных дорог общего пользования, которая в функциональной и обеспечивающей частях системы выполняет роль – бизнес-интегратора.

На создание придорожной инфраструктуры главное влияние оказывает плотность автомобильных дорог, как на международном уровне, так и на республиканских (федеральных) и местных автомобильных дорогах. По результатам литературного обзора выяснилось, что наибольшая плотность автомобильных дорог общего пользования в Беларуси составляет 412, 6 км на 1000 км^2 территории, а минимальная – в Казахстане (25,8 км^2), в среднем по европейским странам она составляет 296,62 км^2, по странам Средней Азии – 63,88 км^2 (рисунок 1) [3].

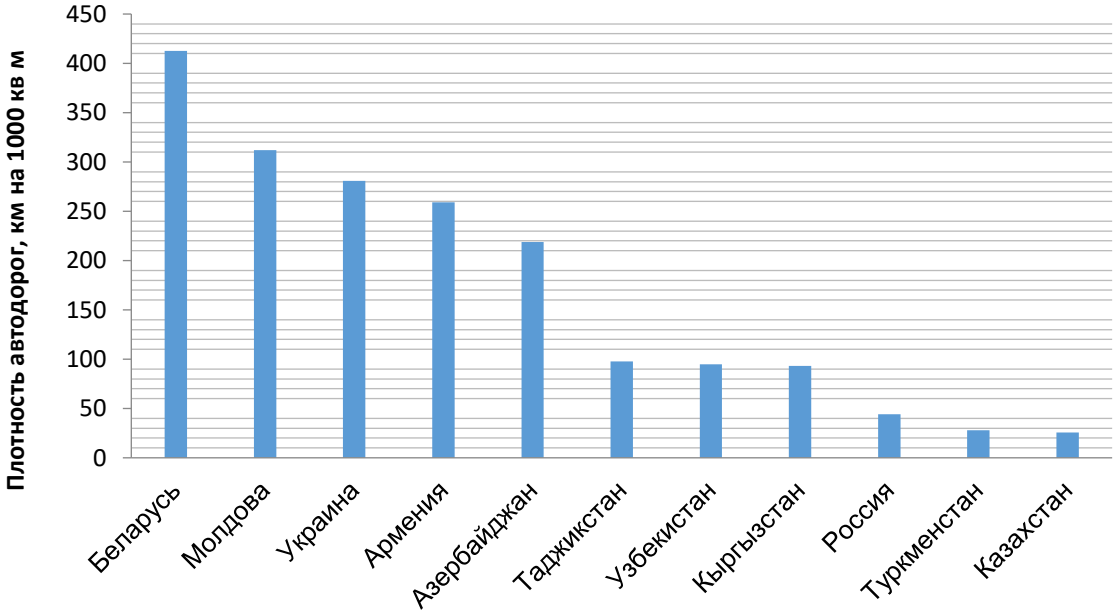


Рисунок 1. Плотность автомобильных дорог стран СНГ

Функциональная схема процесса разрабатывается на основе требований стандартов в области управления, следовательно, необходимо сопоставление требований международных стандартов. При объединении процессов сопоставляется и атрибут «механизм», в особенности компетенция человеческих ресурсов, задействованных в процессе.

На основе литературного анализа нами выбран следующий способ выявления 8 однородных процессов [4] и разработан перечень процессов каждой из подсистем ИСМК. Инфраструктурными составляющими придорожного сервис-менеджмента являются следующие процессы:

Процесс 1. Медицинское обслуживание участников движения.

Процесс 2. Техническое обслуживание и ремонт автомобилей.

Процесс 3. Обеспечения горюче-смазочными материалами.

Процесс 4. Организация пунктов питания.

Процесс 5. Организация отдыха водителей и пассажиров.

Процесс 6. Информационное обеспечение пассажиров и водителей на протяжении всей автомобильной магистрали.

Процесс 7. Эвакуационное обеспечение транспортных средств.

Процесс 8. Подготовка кадров (кадровый менеджмент).

Шкала соответствия двух процессов по характеристике «результаты процесса» представлена в таблице 1.

Таблица 1.

Характеристики результатов выбора при объединении различных видов сервисных объектов

Характеристика результатов	**Правило выбора**
Идентичные результаты процессов	Повышение производительности одного из процессов с целью исключения другого процесса
Несущественные различия результатов процессов	Возможно объединение процессов
Существенные различия результатов процессов	Невозможно объединение процессов

Модель шкалы соответствия двух и более процессов по характеристике «требования стандартов в области управления к процессам» представлена на рисунке 2.

Из приведенных предпосылок теоретические исследования содержат следующие задачи:

- экспертное определение рангов выше перечисленных бизнес-процессов и разработка модели агрегированного оценивания качества исследуемого проекта;

- построение структурно-функциональной IDEF-модели исследуемых бизнес-процессов в стандарте ISO 2000;

- разработка имитационных моделей для целей оптимизации бизнес-процессов в горизонтальном и вертикальном измерениях;

- разработка модели количественной оценки рисков принятия решений в системе интегрированной придорожной бизнес-деятельности.

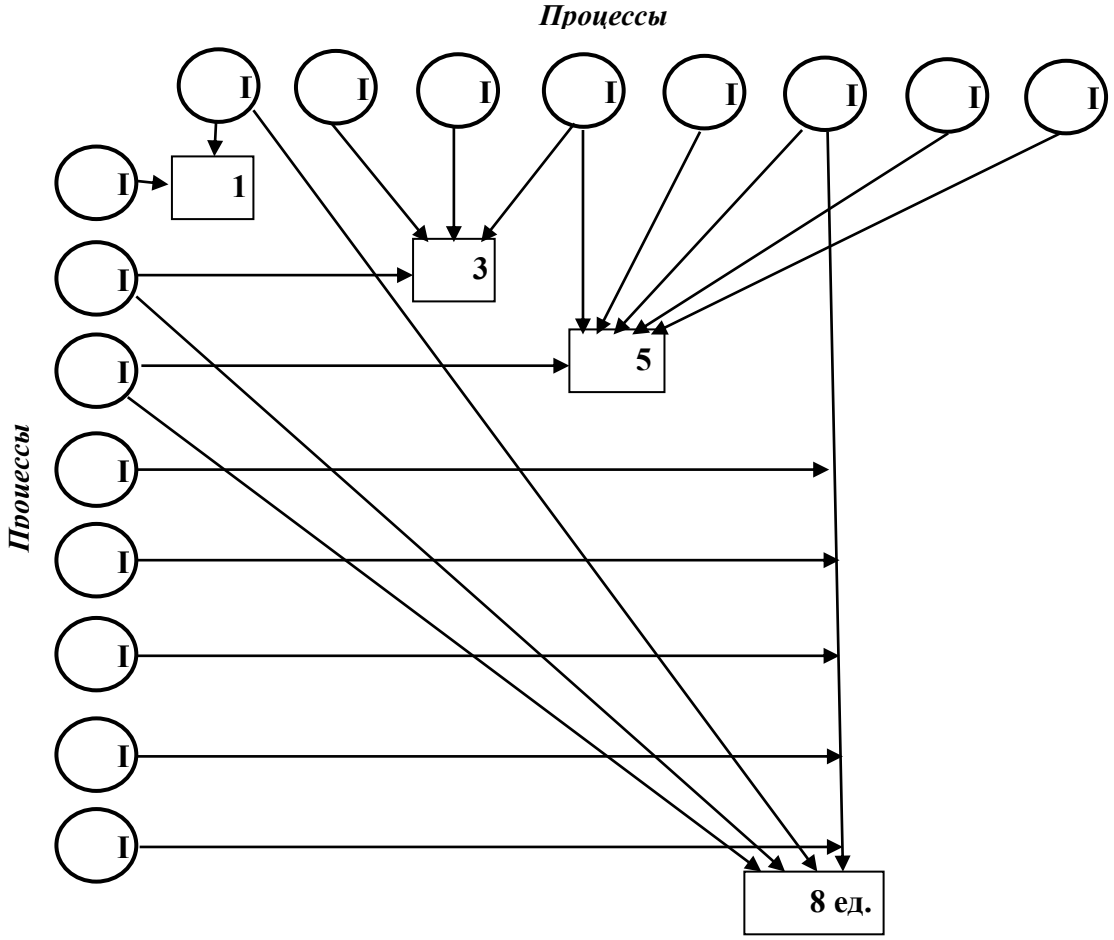


Рисунок 2. Модель объединения процессов при создании придорожного сервисного объекта

При составлении количественного состава придорожных объектов в первую очередь необходимо оценить степень риска параметров проектируемой системы в условиях статистической неопределенности принятия решений. Статистическая неопределенность обусловлена законами распределения параметров моделирования, т.е. объединение двух и более процессов в один объект.

Литература

1. Ф. Котлер. Основы маркетинга. /пер. с анг. В.Б. Боброва. //под ред. Е.М. Пеньковой. – С-П: АО «КОРУНА», АОЗТ «ЛИТЕРА ПЛЮС». – 1994

2. Imkeep E. Tourism Planning. An Integrated and Sustainable Development Approach. – New York: 1991.

3. Киялбаев А.К., Киялбай А.А. Обоснование принципов организации инфраструктуры придорожного сервиса. Научная монография. /под ред. д.т.н., профессора А.К. Киялбаева. – М.: МААДО, 2017. – 244 с.

4. Соколов А. В. Формирование инфраструктуры дорожного сервиса в России. /автореф. дис. на соис. уч. степ. канд. экон. Наук. //А. В. Соколов. – М.: МАДИ, 2004. – 24 с.

No 187 (2026)

Sciences of Europe
(Praha, Czech Republic)

ISSN 3162-2364
The journal is registered and published in Czech Republic.
Articles in all spheres of sciences are published in the journal.

Journal is published in Czech, English, Polish, Russian, Chinese, German and French, Ukrainian.
Articles are accepted each month.
Frequency: 24 issues per year.
Format - A4
All articles are reviewed
Free access to the electronic version of journal

Edition of journal does not carry responsibility for the materials published in a journal.
Sending the article to the editorial the author confirms it's uniqueness and takes full responsibility for possible consequences for breaking copyright laws.

Chief editor: Petr Bohacek
Managing editor: Michal Hudecek

- Jiří Pospíšil (Organic and Medicinal Chemistry) Zentiva
- Jaroslav Fähnrich (Organic Chemistry) Institute of Organic Chemistry and Biochemistry Academy of Sciences of the Czech Republic
- Rasa Boháček – Ph.D. člen Česká zemědělská univerzita v Praze
- Naumov Jaroslav S., MD, Ph.D., assistant professor of history of medicine and the social sciences and humanities. (Kiev, Ukraine)
- Viktor Pour – Ph.D. člen Univerzita Pardubice
- Petrenko Svyatoslav, PhD in geography, lecturer in social and economic geography. (Kharkov, Ukraine)
- Karel Schwaninger – Ph.D. člen Vysoká škola báňská – Technická univerzita Ostrava
- Václav Pittner -Ph.D. člen Technická univerzita v Liberci
- Dudnik Oleg Arturovich, Doctor of Physical and Mathematical Sciences, Professor, Department of Physical and Mathematical management methods. (Chernivtsi, Ukraine)
- Konovalov Artem Nikolaevich, Doctor of Psychology, Professor, Chair of General Psychology and Pedagogy. (Minsk, Belarus)

«Sciences of Europe» -
Editorial office: Křižíkova 384/101 Karlín, 186 00 Praha

E-mail: info@european-science.org
Web: www.european-science.org